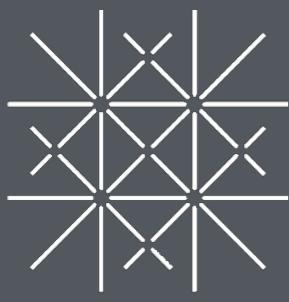


Analysing Trajectory types

Dirk U. Wulff University of Basel & MPI for Human Development

EADM summer school @ Salzburg, 2018

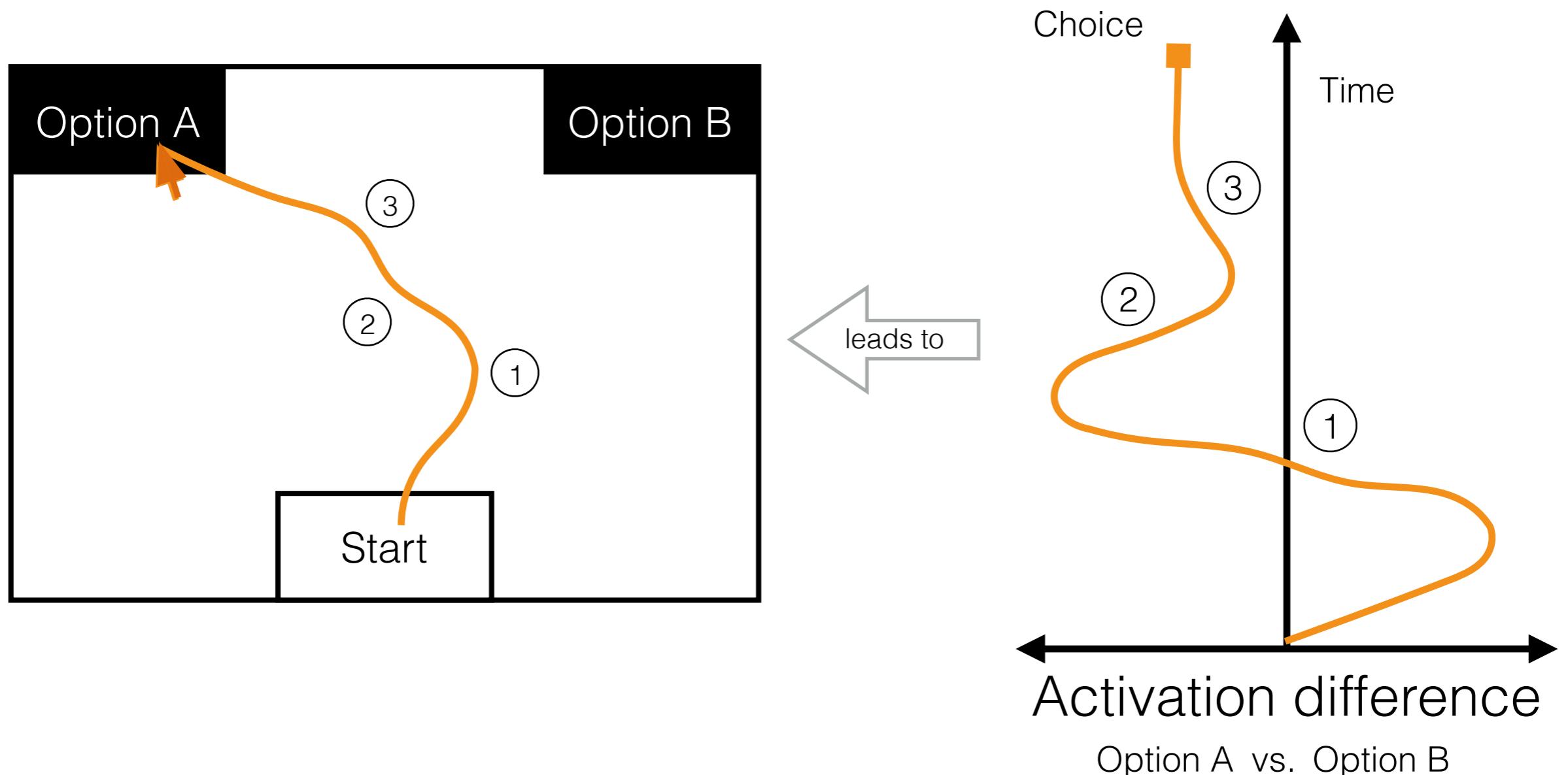


UNI
BASEL



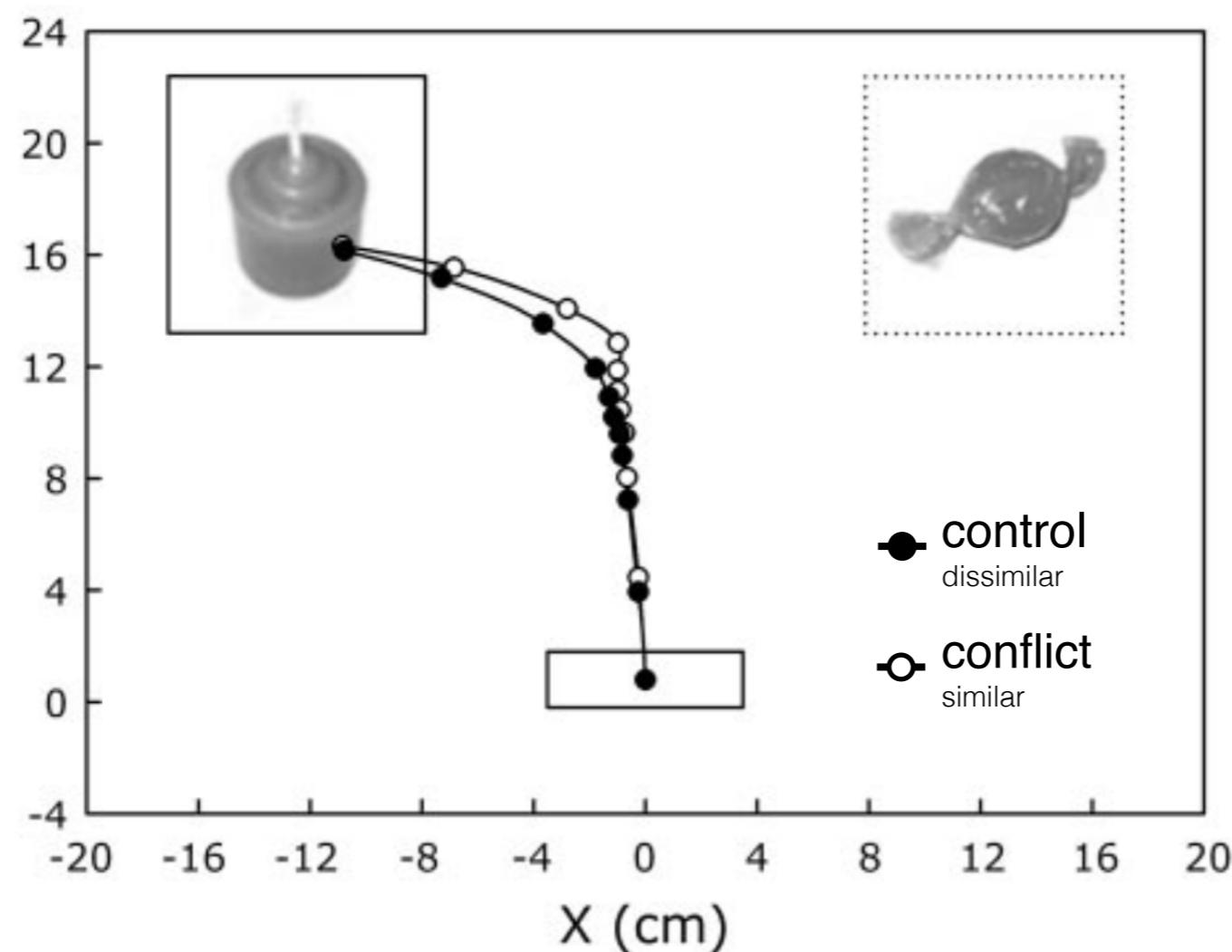
Mousetracking

Measuring the continuous mind (?)



Spivey et al. 2005

PNAS



Spivey et al., 2005

Conclusions

„By recording the streaming x, y coordinates of continuous goal-directed hand movement in a spoken-language task, online accrual of acoustic–phonetic input and competition between partially active lexical representations are revealed in the shape of the movement trajectories. This hand-movement paradigm allows one to project the internal processing of spoken-word recognition onto a two-dimensional layout of continuous motor output, providing a concrete visualization of the attractor dynamics involved in language processing.“

(Spivey, Grosjean, & Knoblich, 2005, p.10393)

Spivey et al., 2005

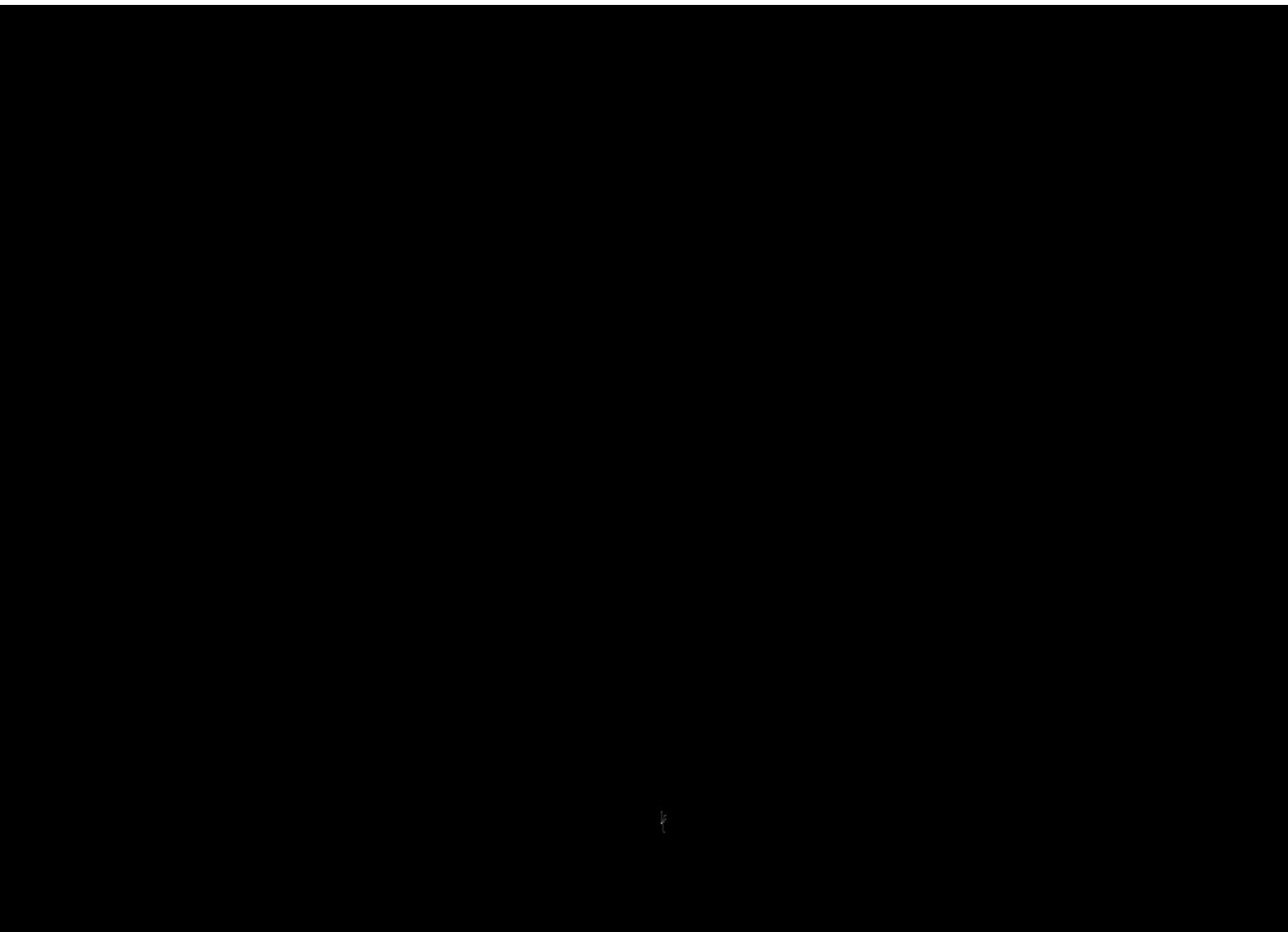
on discrete effects and aggregation

„In principle, it could be the case that, as with saccadic eye movements, there are some trials in which the competitor object does not attract the motor output and other trials in which it does. [...] When averaged, this hypothetical data pattern would produce mean movement trajectories that could falsely suggest simultaneous partial activation and competition among multiple lexical representations.“

(Spivey, Grosjean, & Knoblich, 2005, p.10395)

Raw trajectory video

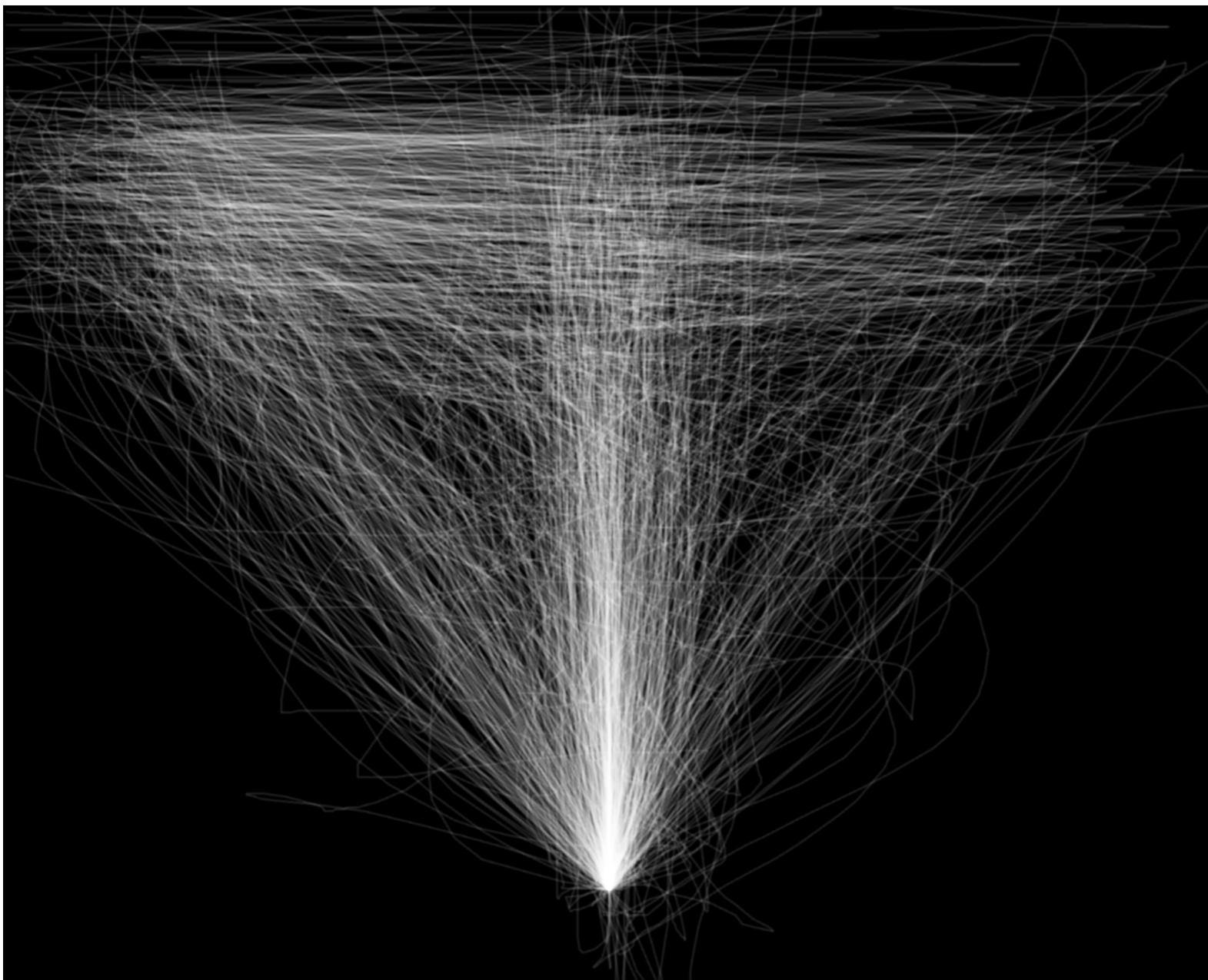
Spivey et al. 2005



```
# create gif  
mt_animate(data,  
            density = 5,  
            seconds = 10)
```

Heatmap

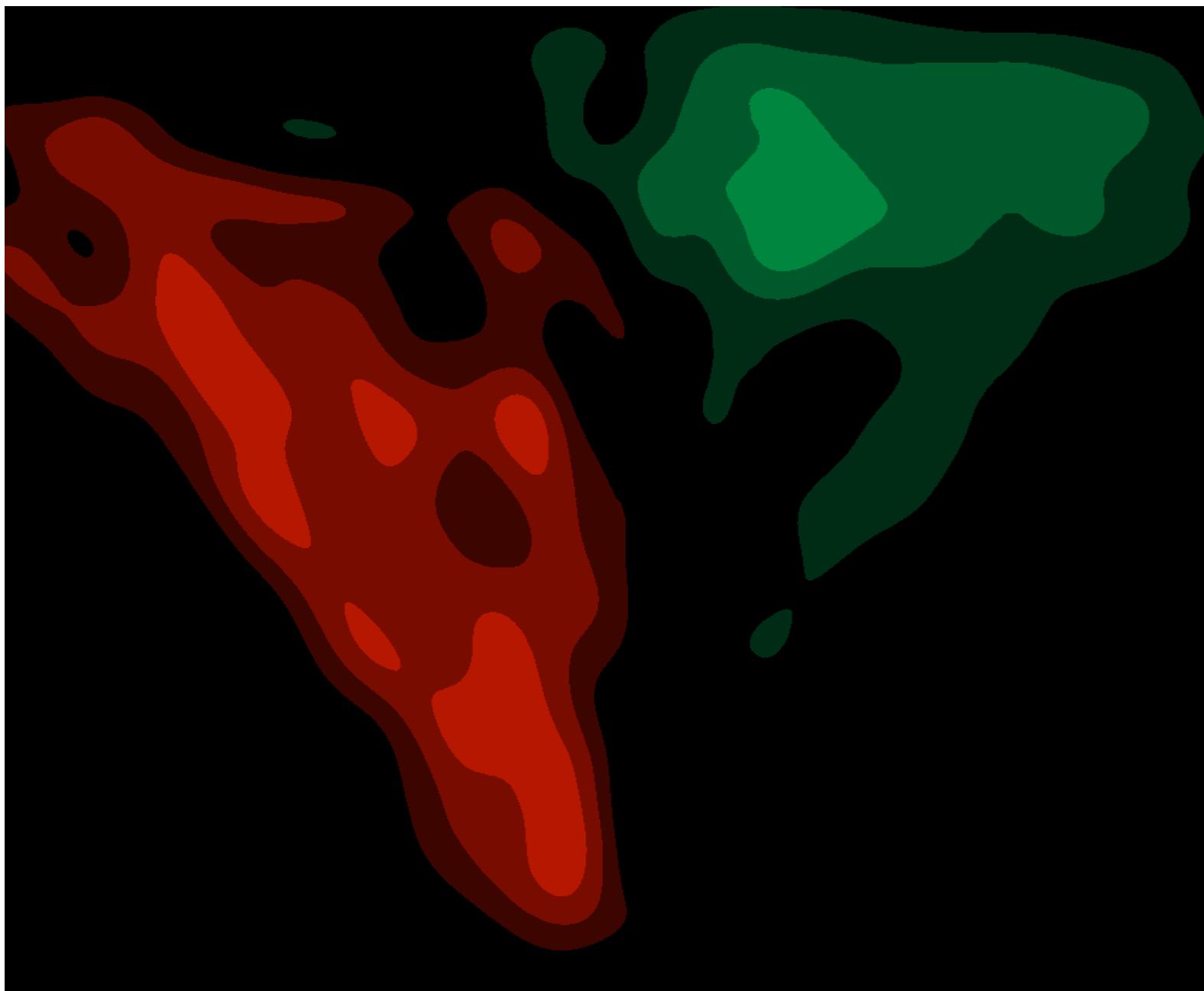
Spivey et al. 2005



```
# create heat map  
mt_heatmap(data,  
filename = 'Spivey.tiff',  
xres = 2000)
```

Difference map

Spivey et al. 2005



```
# create heat map
mt_heatmap(data,
  filename = 'Spivey_diff.tiff',
  smooth_radius = 20,
  n_shades = c(10,5),
  upscale = 2,
  mean_image = .3,
  mean_color = .2,
  bounds =
    c(-1.1,-.1,1.1,1.7),
  dimensions =
    c('xpos','ypos','vel')
```

Do mouse- and
hand-trajectories
occur in types?

Database

40
articles

2,344 participants

361,607 trajectories



32

2,125

259,153



2

113

4,403



2

50

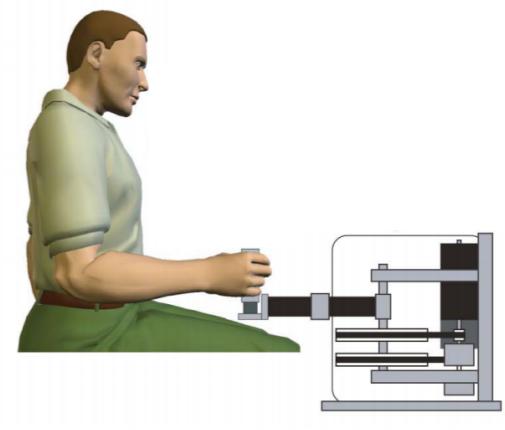
37,786



3

52

26,865



1

4

33,400

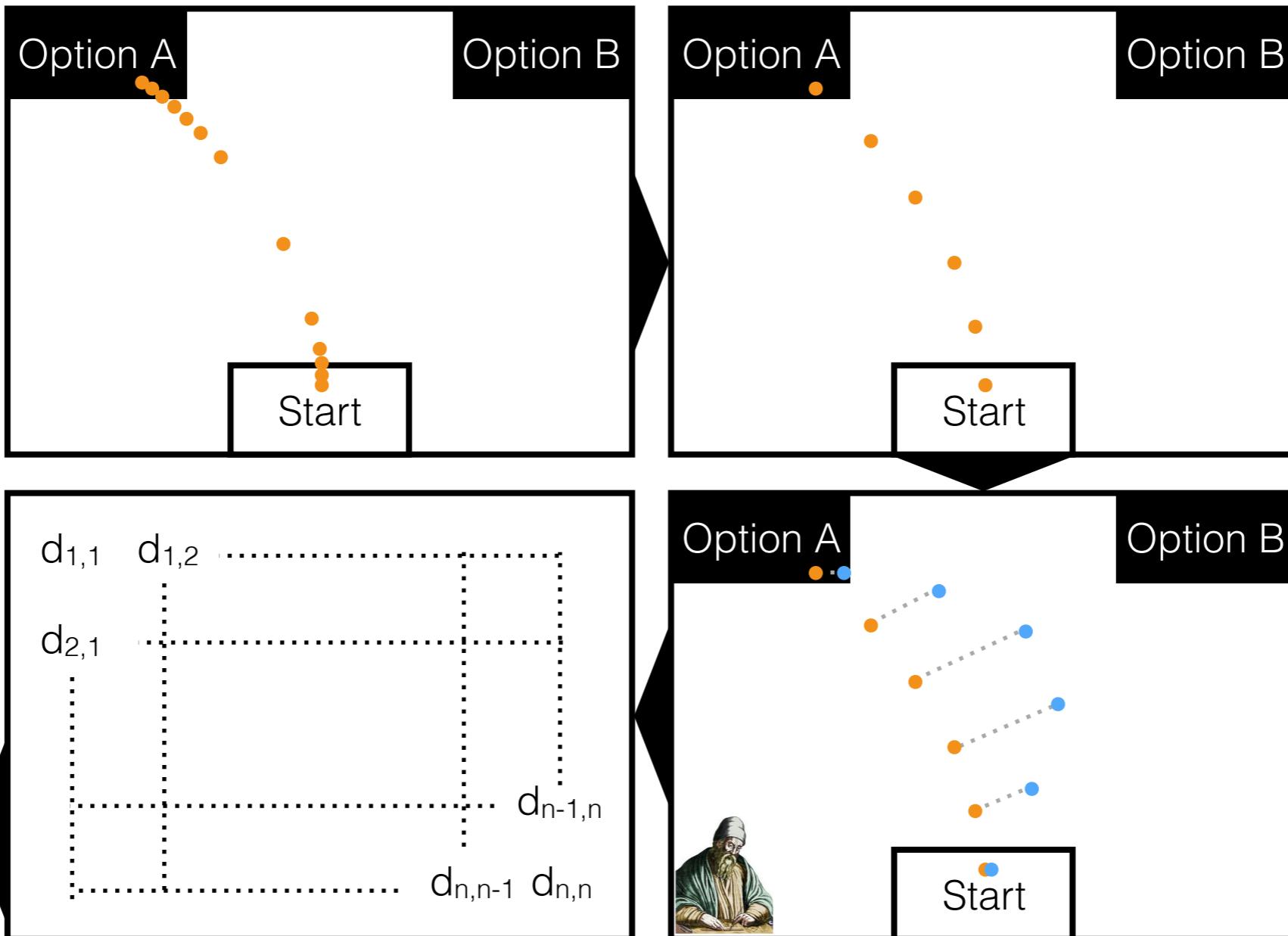
paper

ppt

trials

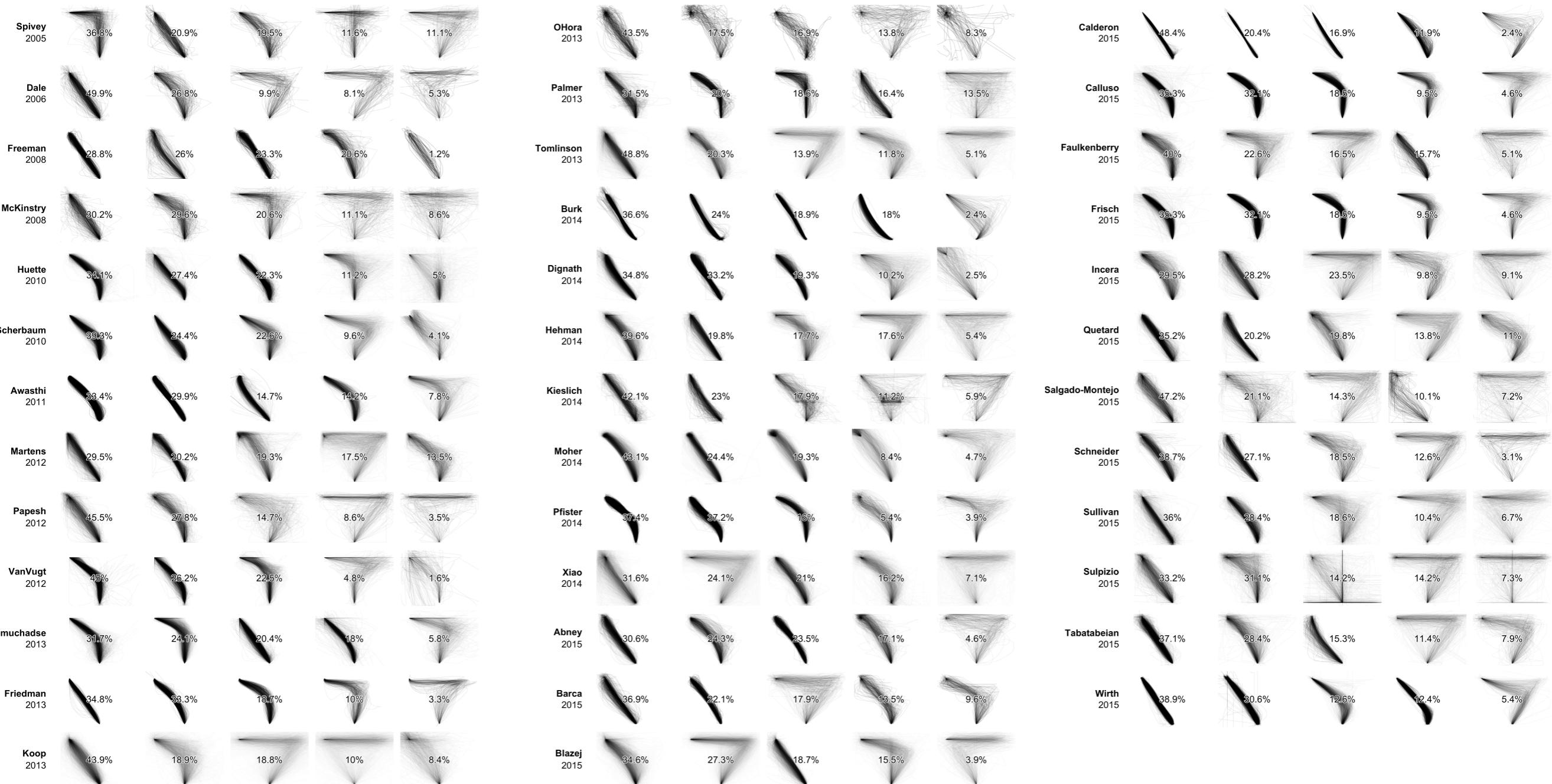
Trajectory clustering

How to?



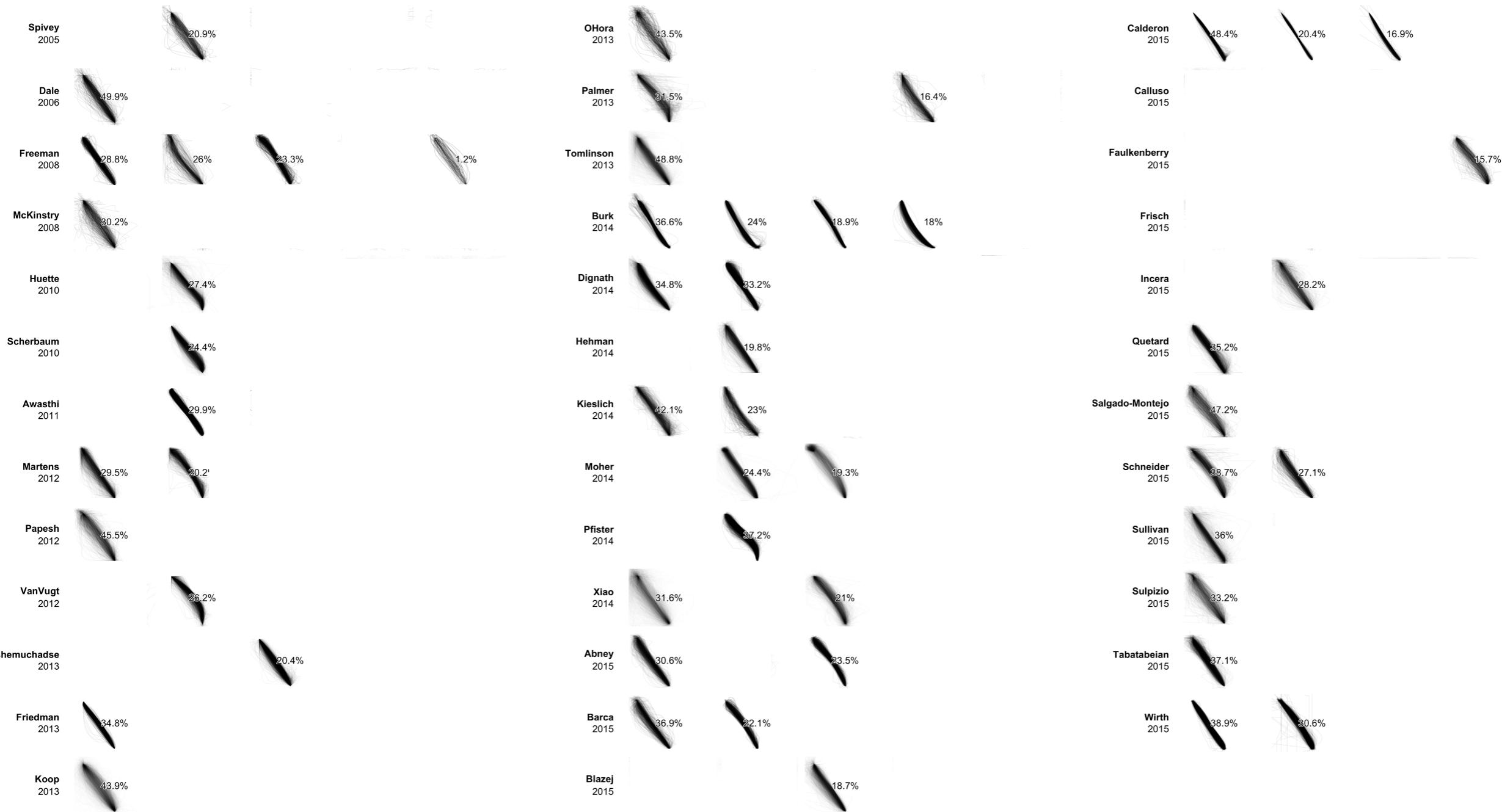
Trajectory clustering

Extracting 5 clusters



Trajectory clustering

Straight lines



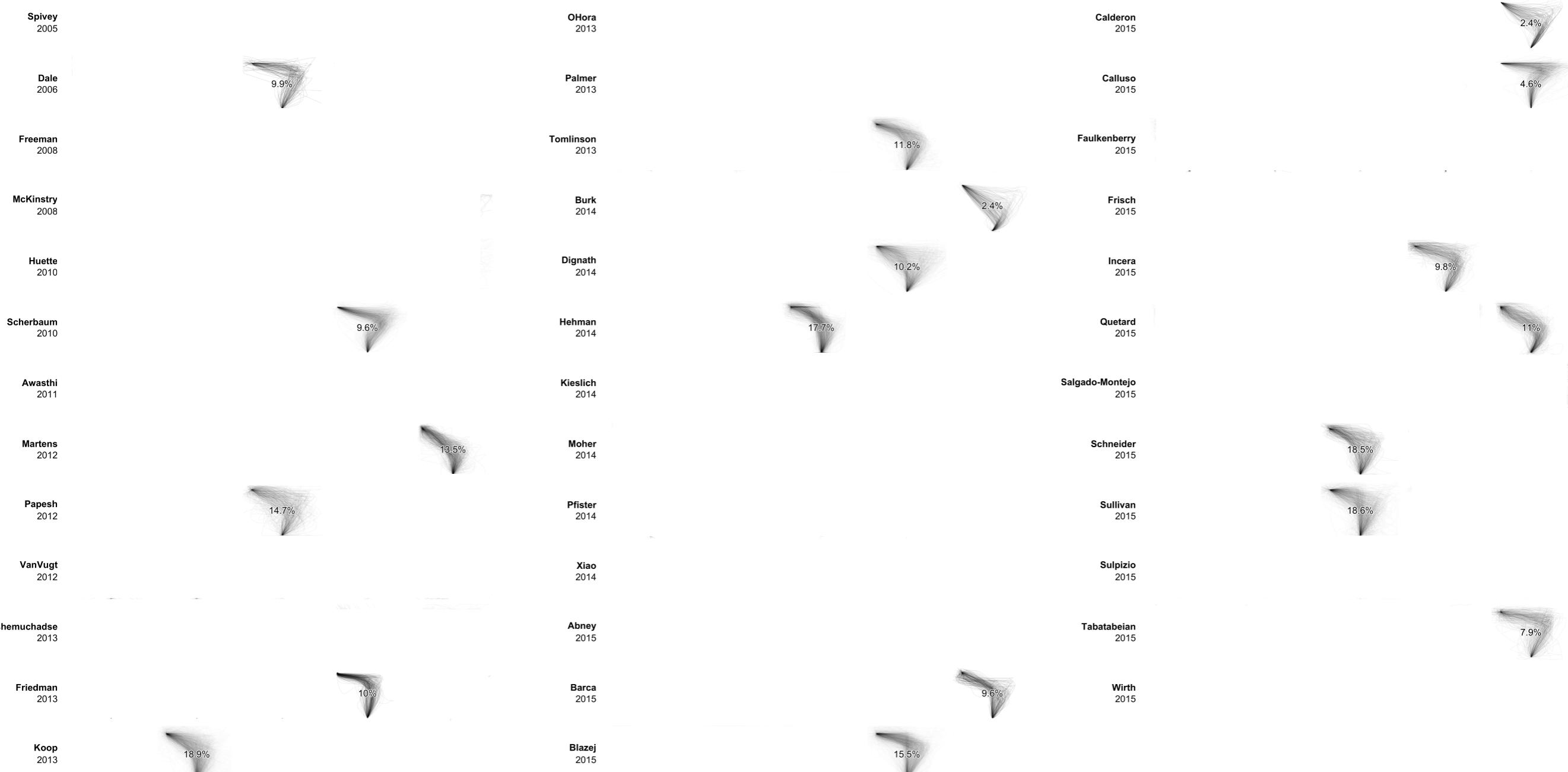
Trajectory clustering

Mild curves



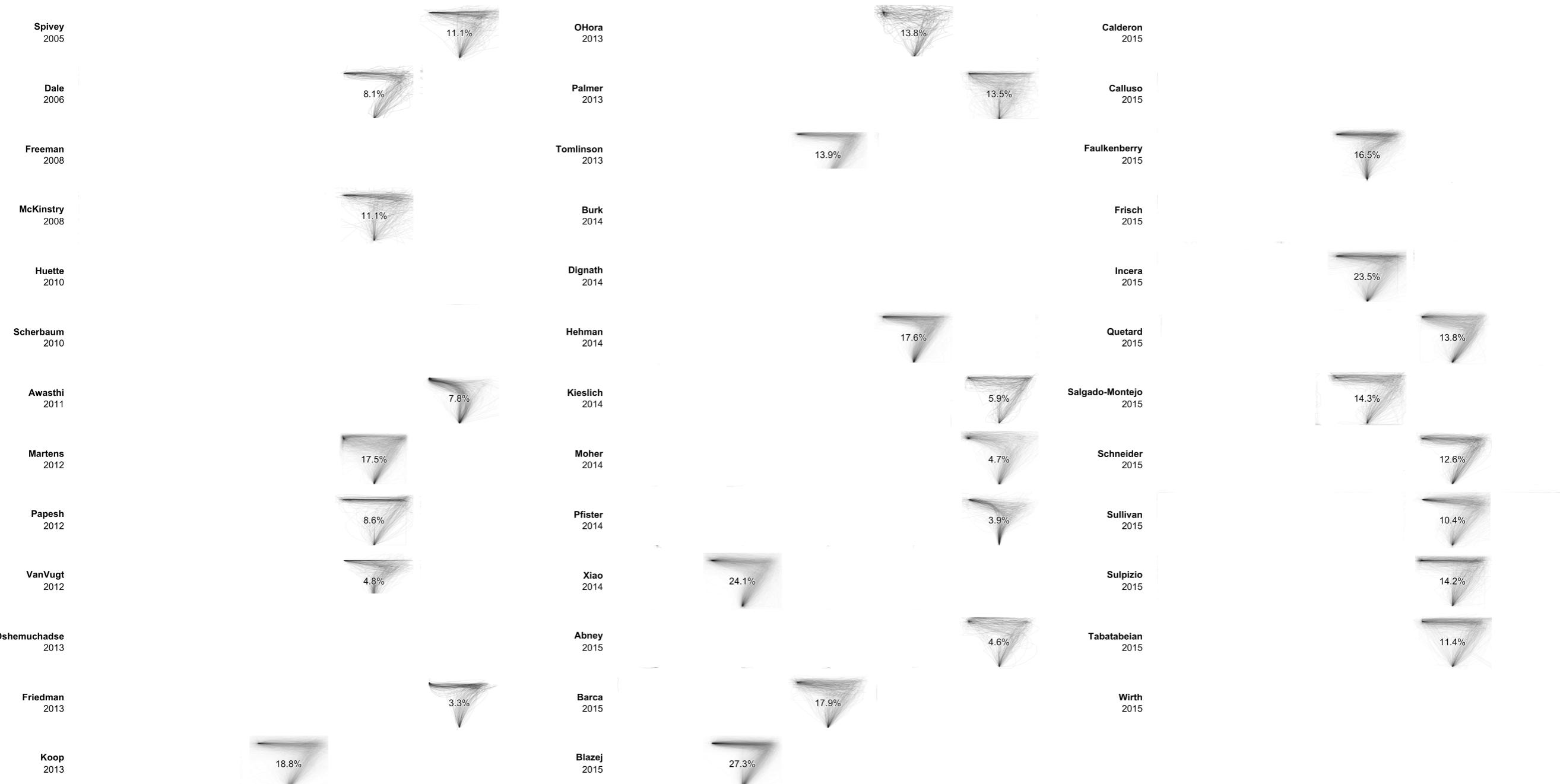
Trajectory clustering

Change of mind



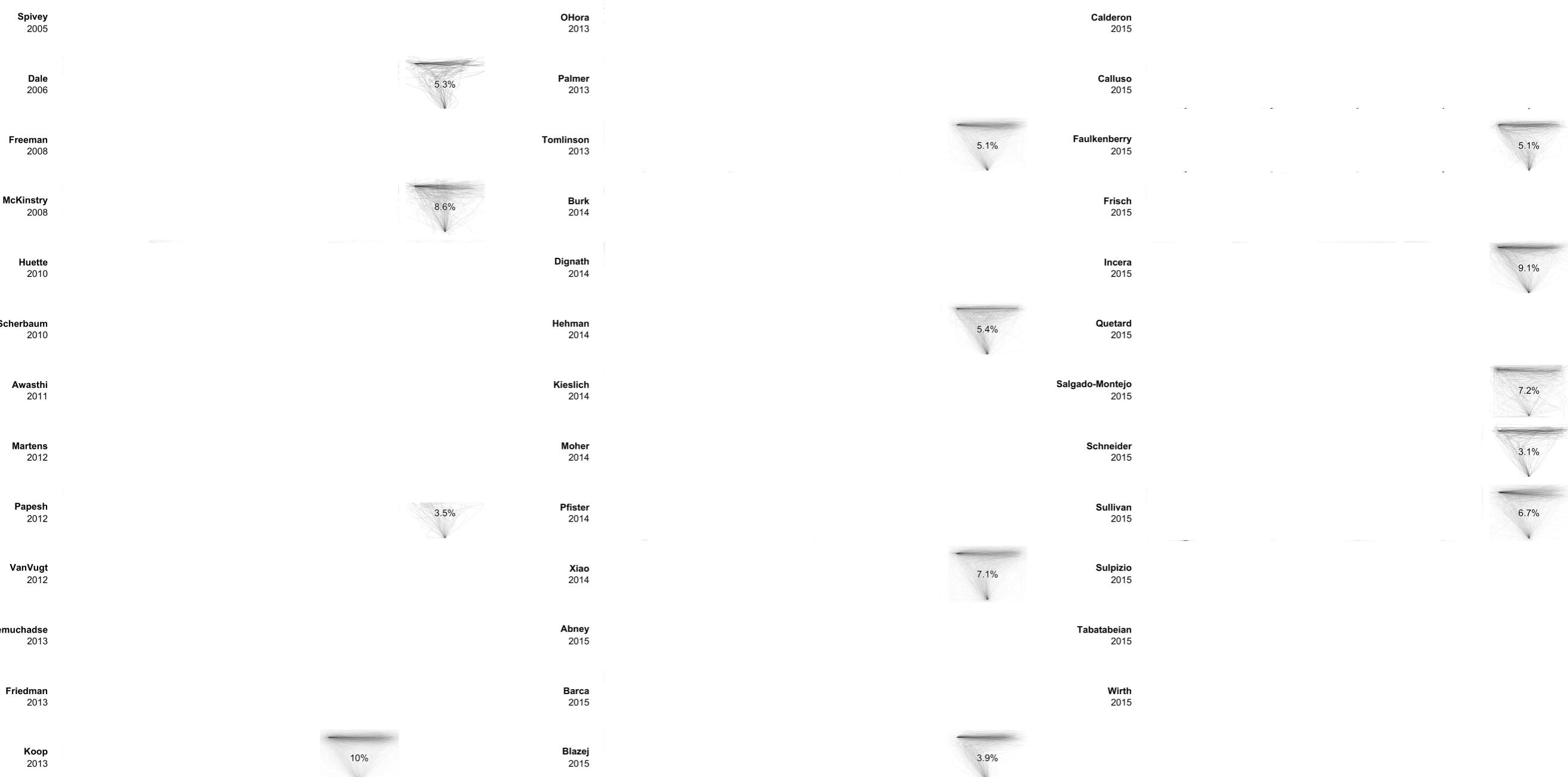
Trajectory clustering

Discrete change of mind



Trajectory clustering

Multiple change of minds

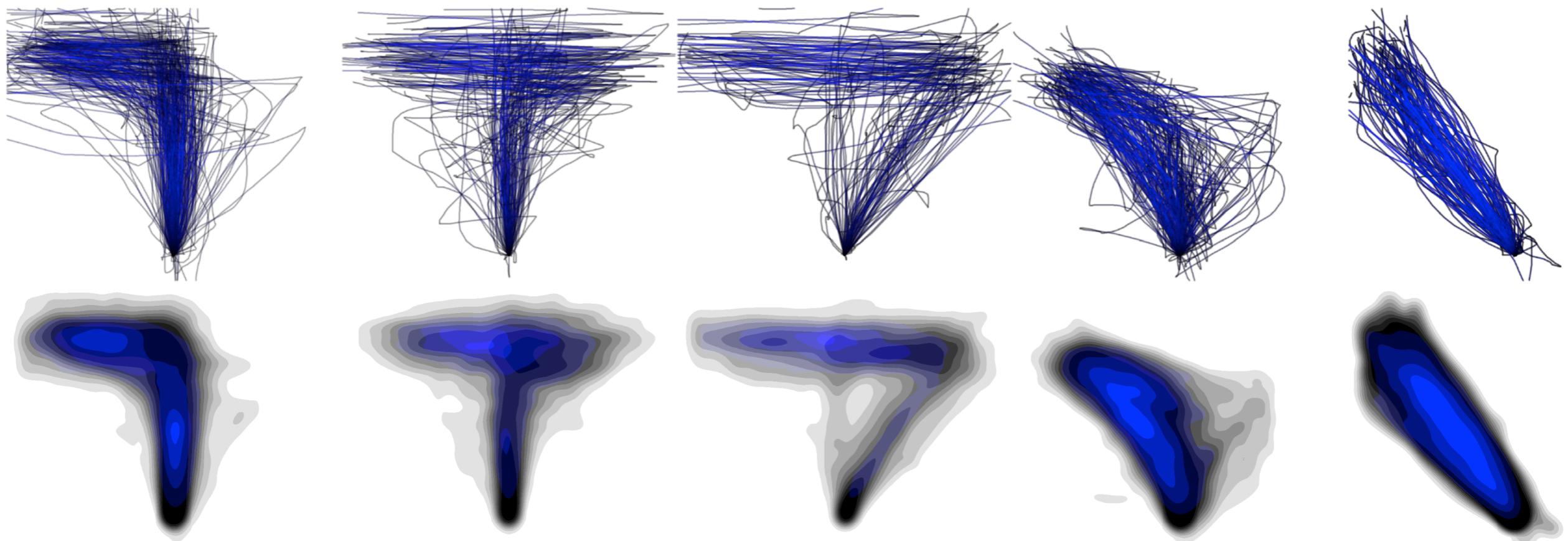


How to analyse
trajectory types?

Exploratory clustering

Spivey et al. 2005

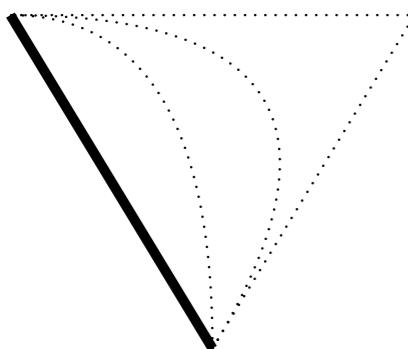
```
# cluster  
data = mt_spatialize(data) # transform trajectories  
data = mt_cluster(data, n_cluster = 5) # cluster trajectories  
  
# plot  
for(i in 1:5) mt_heatmap(mt_subset(data, cluster == i,...),...)
```



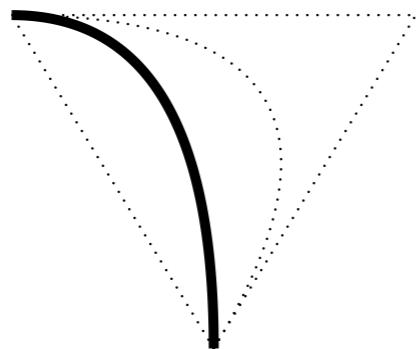
Prototype recognition

Allocate trajectories to closest prototype

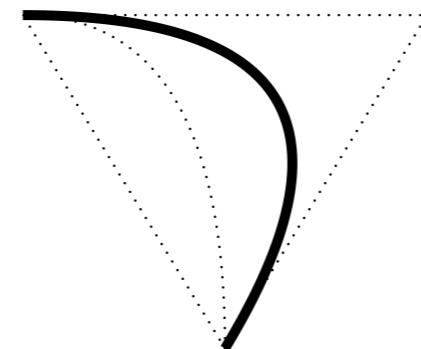
Straight



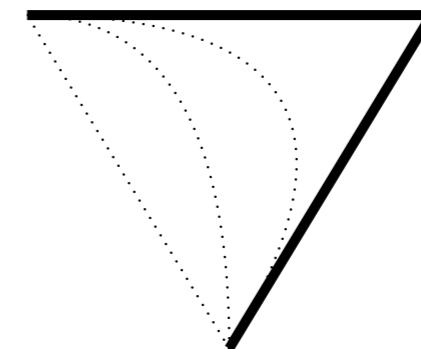
Curved



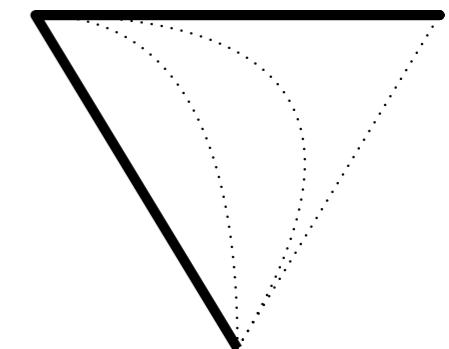
cCoM



dCoM



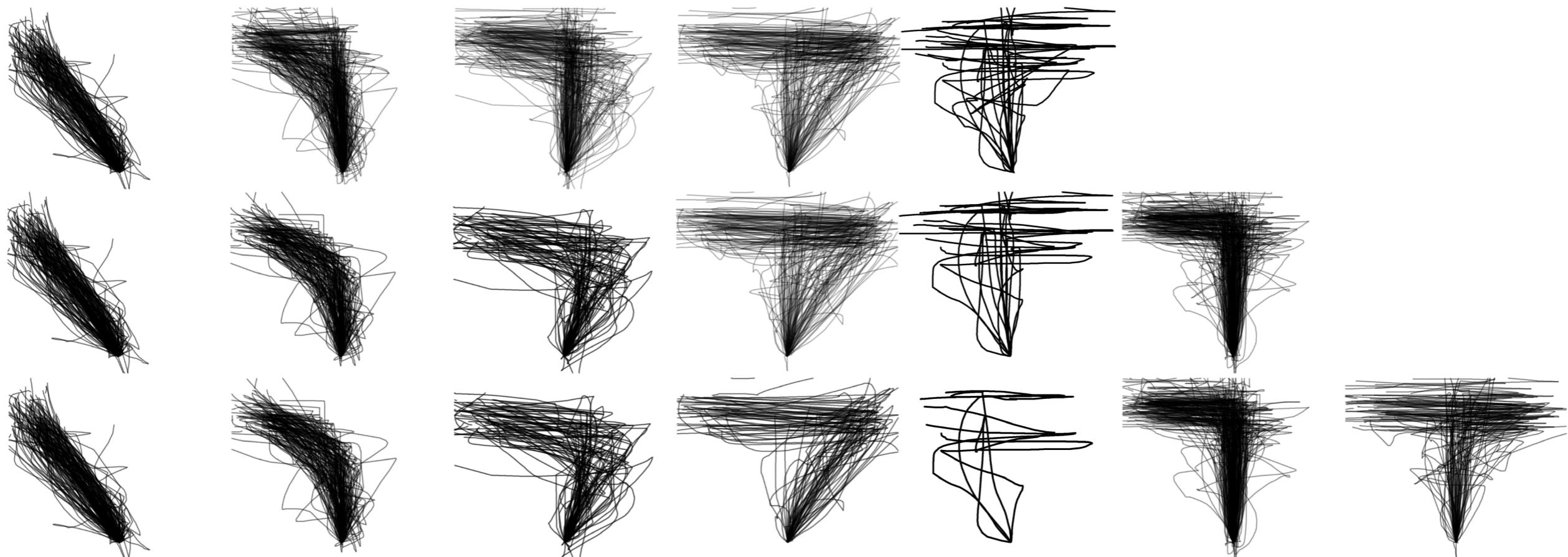
dCoM²



Prototype recognition

Spivey et al. 2005

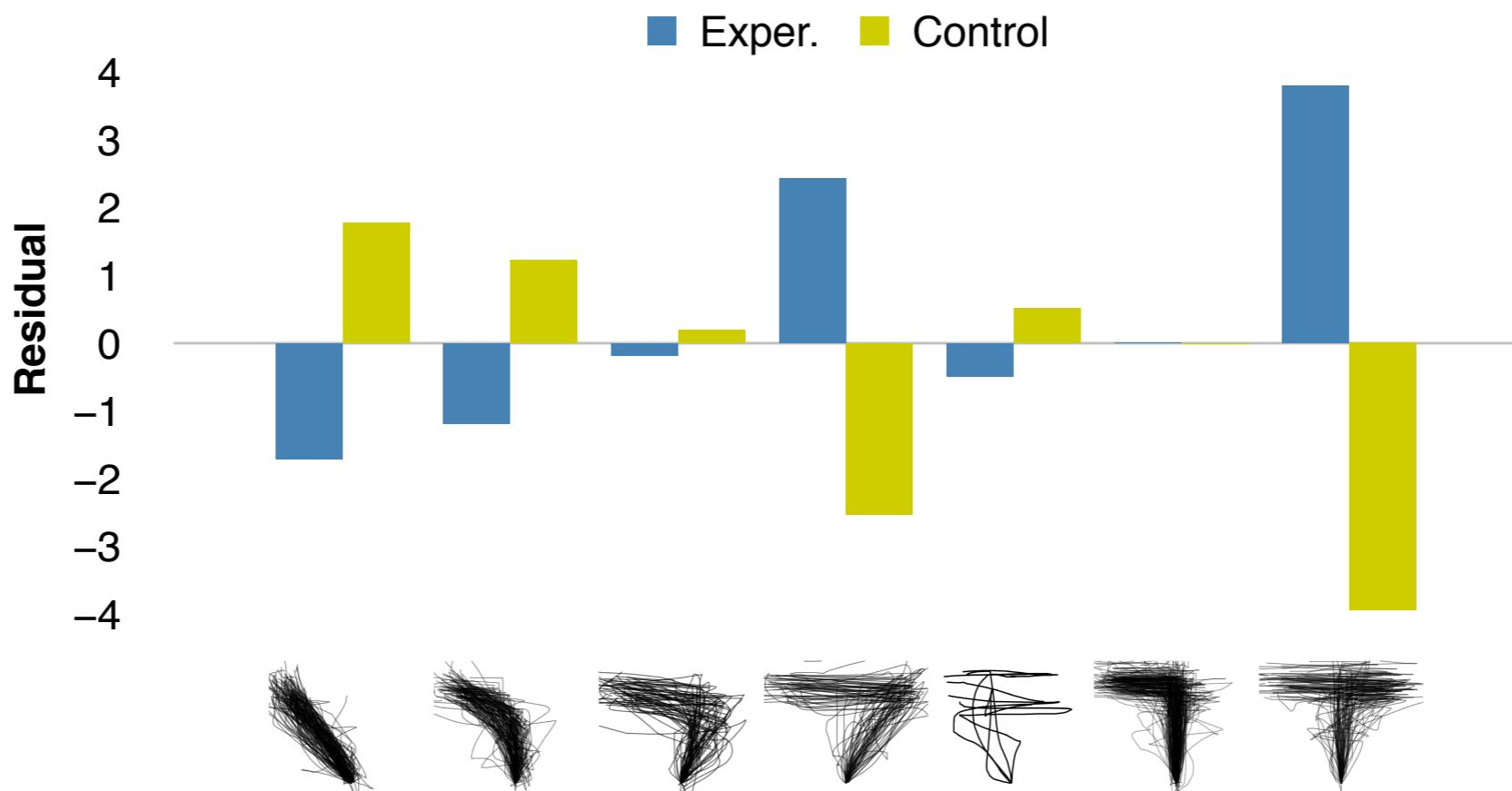
```
# map to prototypes  
data = mt_map(data, prototypes = mt_prototypes)  
  
# add prototypes  
mt_prototypes = mt_add_trajectory(..., xpos = c(0,0,-1), ypos = c(0,1.5,1.5))  
  
# plot  
for(i in 1:5) mt_heatmap(mt_subset(cl, cluster == i,...),...)
```



Statistical analyses

Spivey et al. 2005

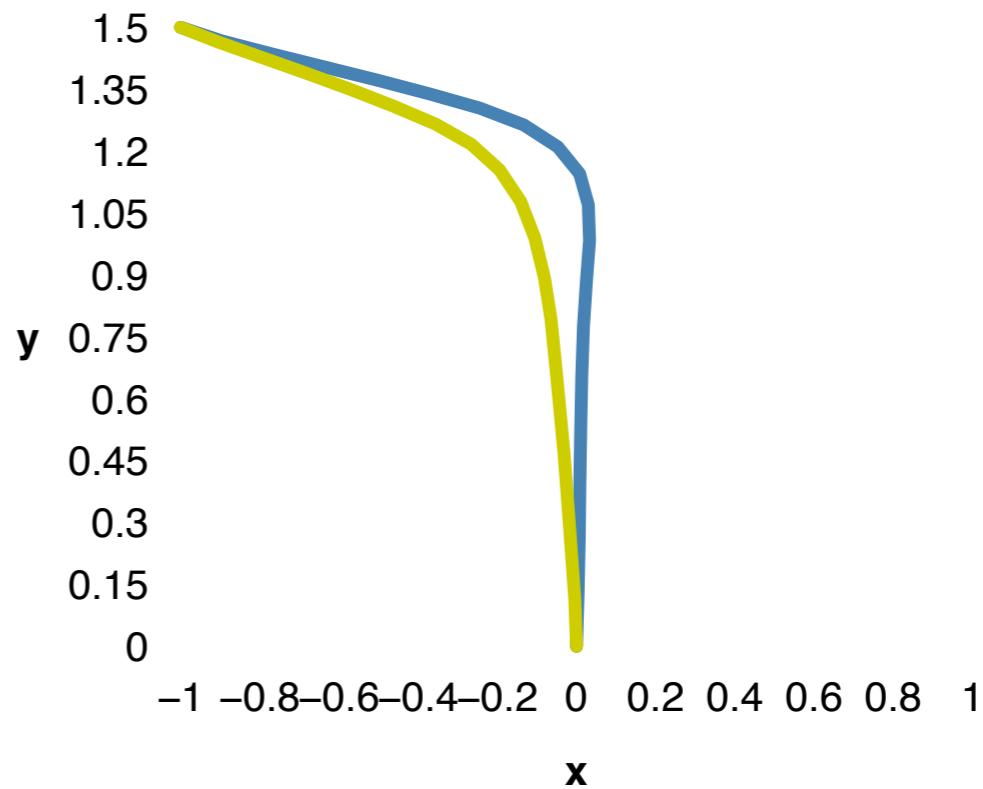
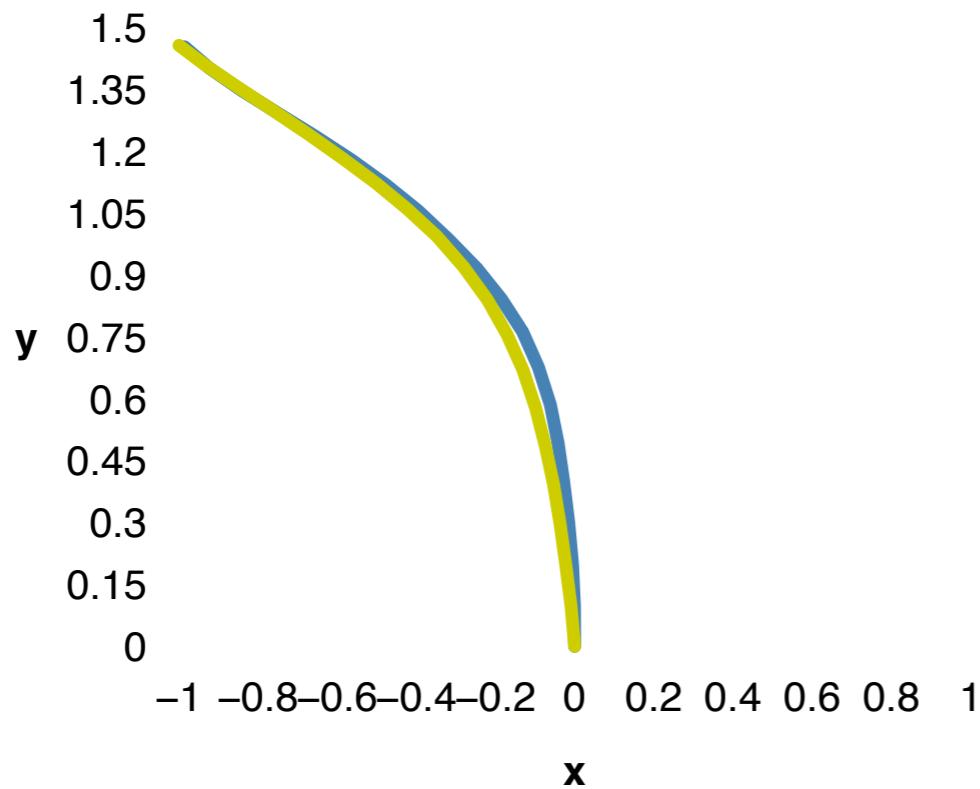
```
# extract frequencies  
frq = rbind(table(data_exp$prototyping$prototype),  
             table(data_con$prototyping$prototype))  
  
# test  
test = chisq(frq)  
  
# residuals  
test$residuals
```



Statistical analyses

Spivey et al. 2005

```
# subset  
data1 = mt_subset(data1,prototype %in% c(1,2,3),check = 'prototyping')  
data2 = mt_subset(data2,prototype %in% c(1,2,3),check = 'prototyping')  
  
# aggregate  
a1 = mt_aggregate(data1, ...) ; a2 = mt_aggregate(data2, ...)  
  
# plot  
plot.new();plot.window(xlim=c(-1, 1), c(0, 1.5))  
lines(a1[,2:3],col='steelblue', lwd=5) ; lines(a2[,2:3],col='yellow3', lwd=5)
```



Conclusions

Mouse-trajectory frequently occur in types

Recommendations

- (a) Plot (or animate) raw trajectories.
- (b) Cluster your data to explore types.
- (c) Evaluate which trajectories drive your effect.
- (d) Base analysis on types rather than AAD, MAD, etc.

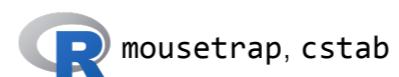
Literature & Resources

Wulff, D. U., Haslbeck, J. M. B., & Schulte-Mecklenbeck (2017). Measuring the (dis-) continuous mind. Manuscript in preparation.

Wulff, D. U., Haslbeck, J. M. B., Kieslich, P. J., Henninger, F., & Schulte-Mecklenbeck, M. (in press). Mouse-tracking: Detecting types in movement trajectories. In M. Schulte-Mecklenbeck, A. Kühberger, & J. G. Johnson (Eds.), *A Handbook of Process Tracing Methods*. New York: Taylor & Francis.

Kieslich, P. J., Henninger, F., Wulff, D. U., Haslbeck, J. M. B., & Schulte-Mecklenbeck, M. (in press). Mouse-tracking: A practical guide to implementation and analysis. In M. Schulte-Mecklenbeck, A. Kühberger, & J. G. Johnson (Eds.), *A Handbook of Process Tracing Methods*. New York: Taylor & Francis.

Kieslich, P. J., Wulff, D. U., Henninger, F., Haslbeck, J. M. B., & Schulte-Mecklenbeck, M. (2016). Mousetrap: An R package for processing and analyzing mouse-tracking data. Manuscript in preparation.



mousetrap, cstab



Jonas M. B.
Haslbeck



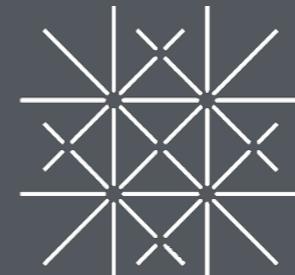
Pascal J.
Kieslich



Felix
Henninger



Michael
Schulte-Mecklenbeck

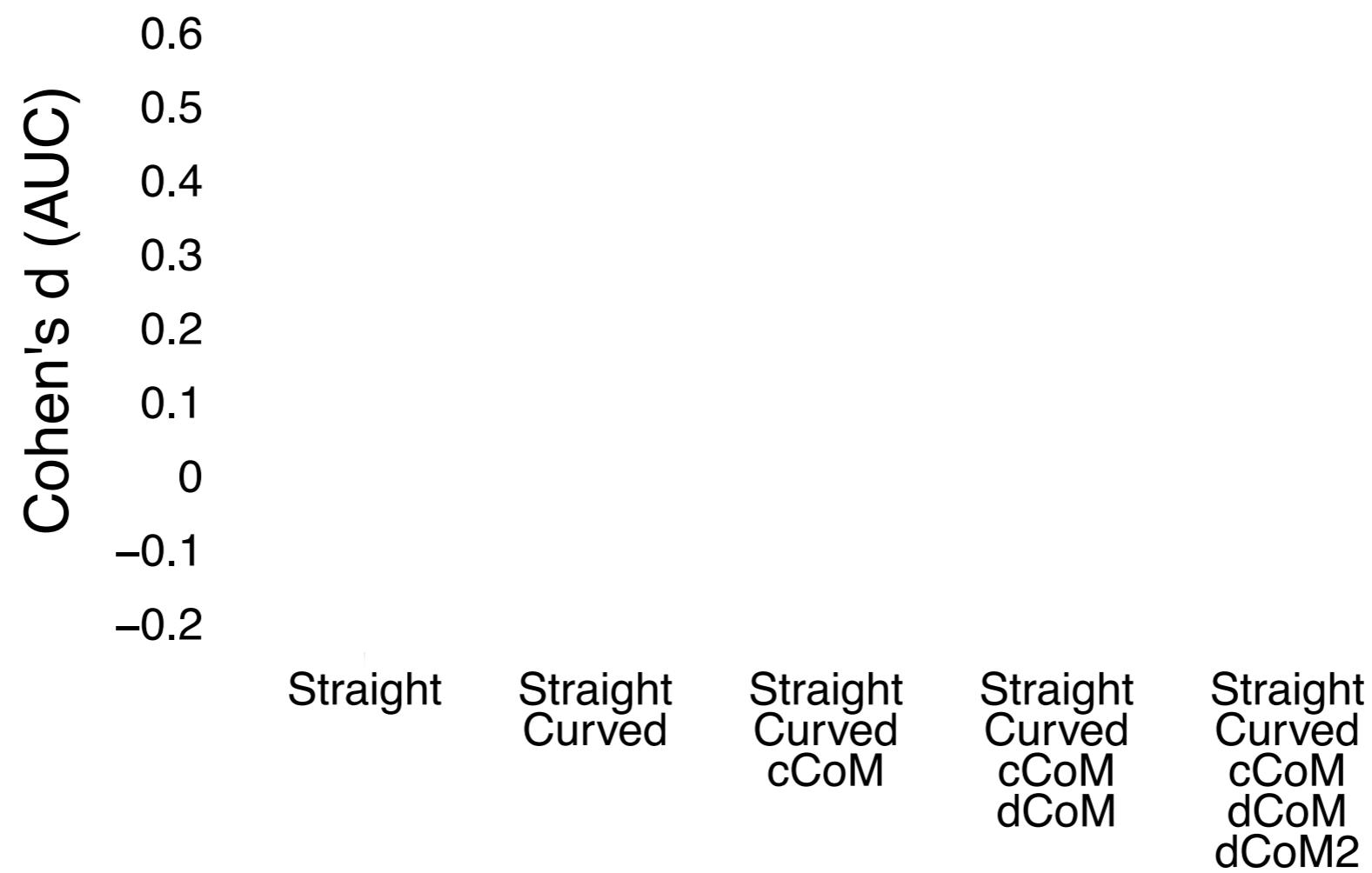
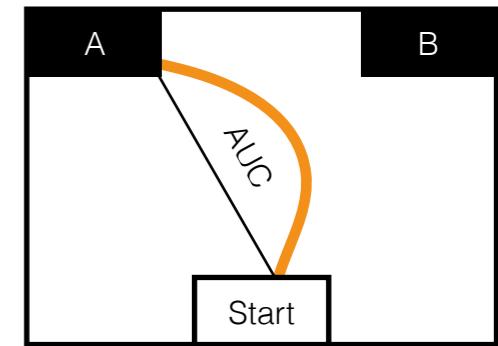


UNI
BASEL



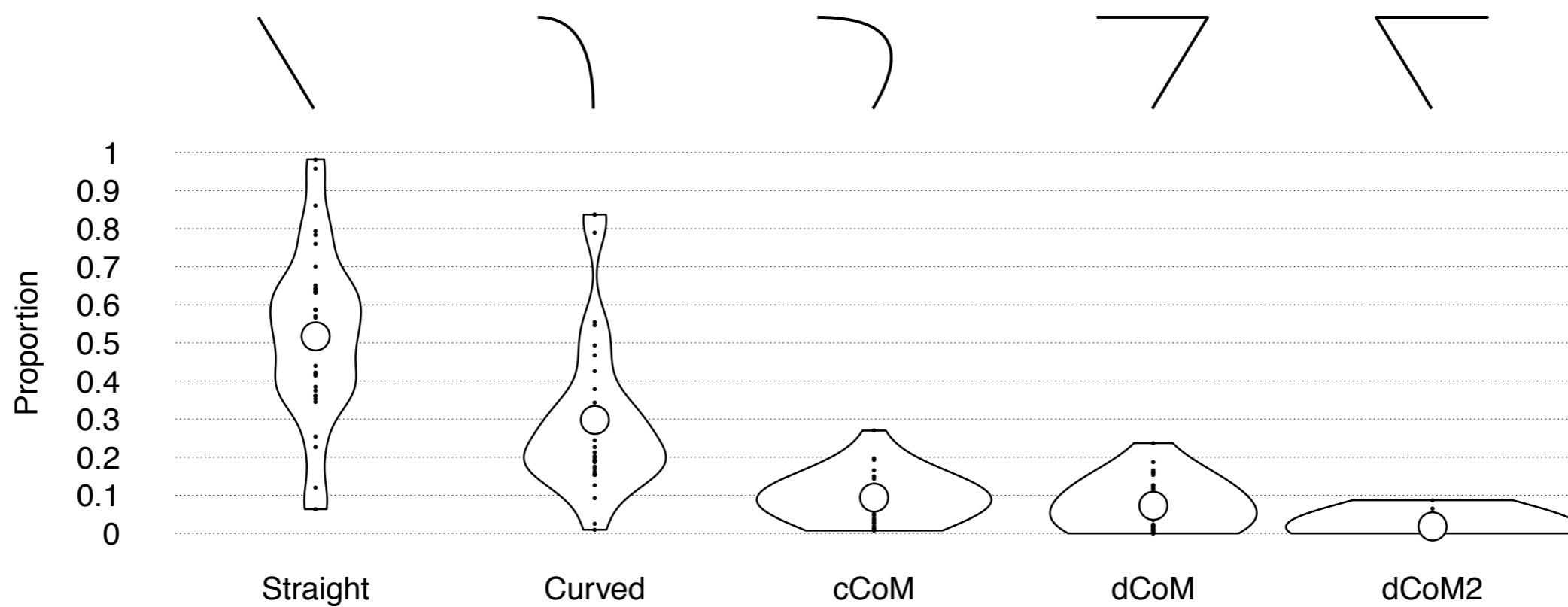
Experimental effect

Conflict - Control



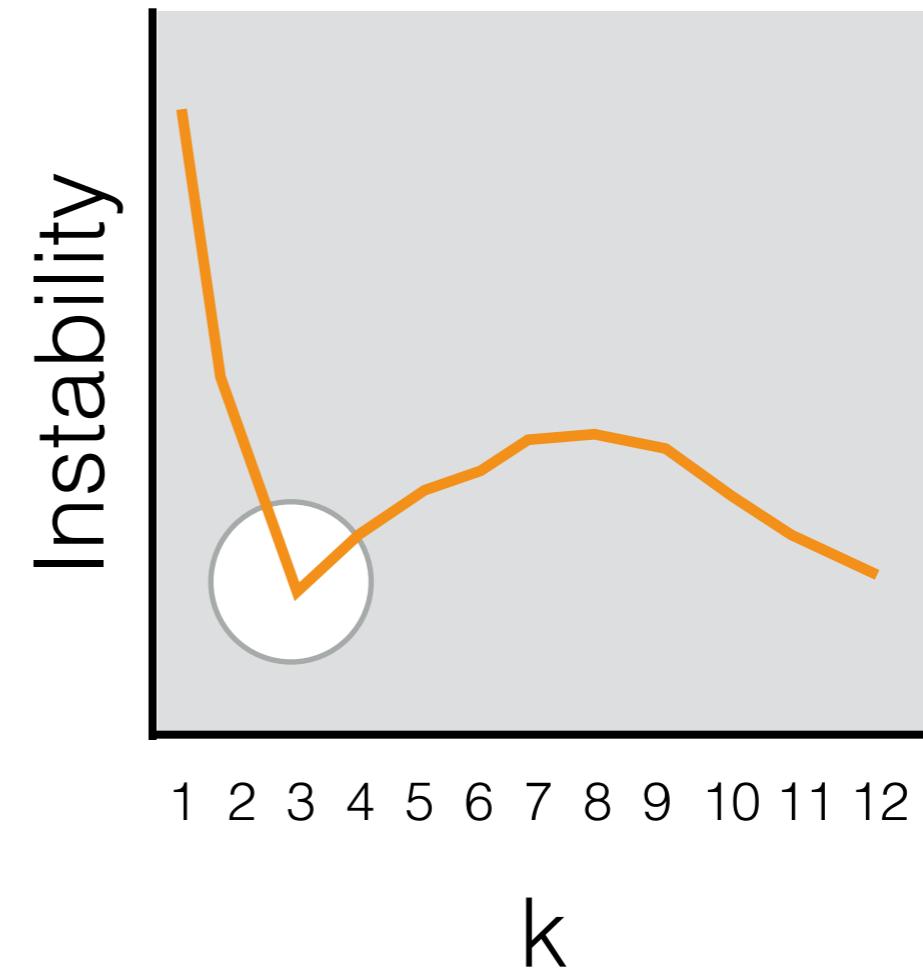
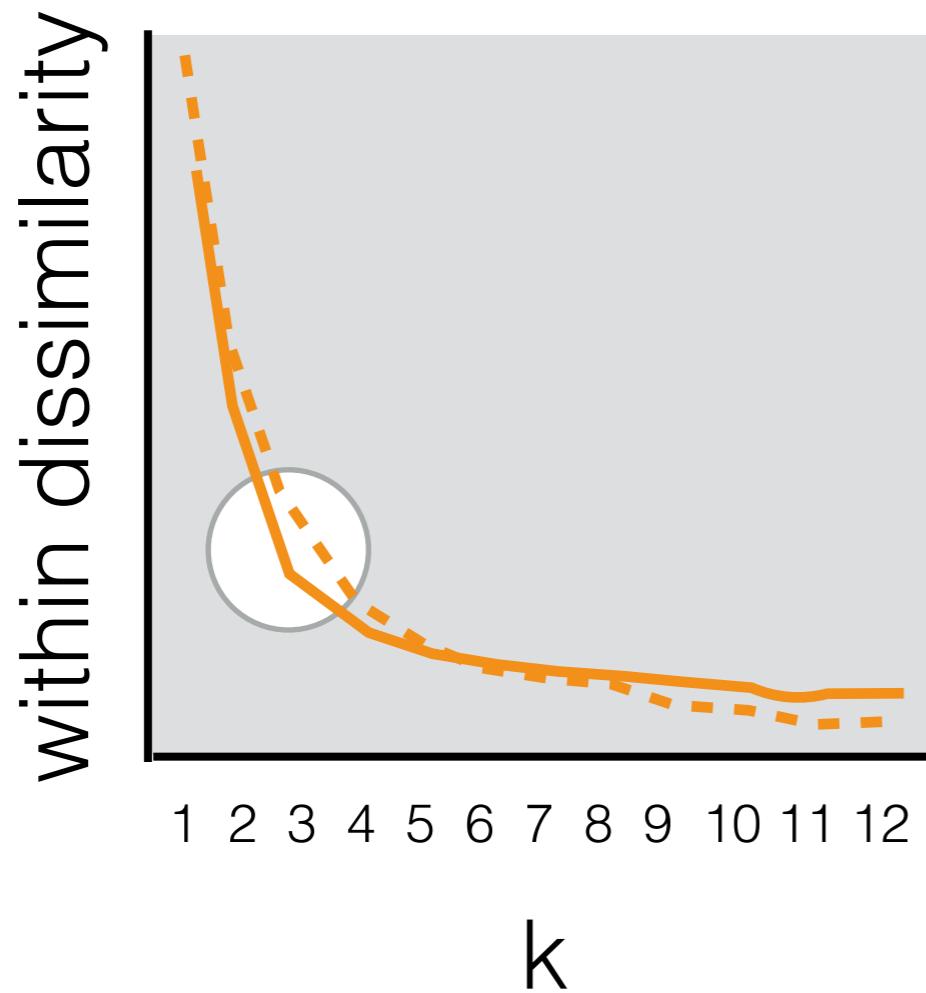
Prototype recognition

“Not all trajectories are curved”



How many clusters?

k-selection

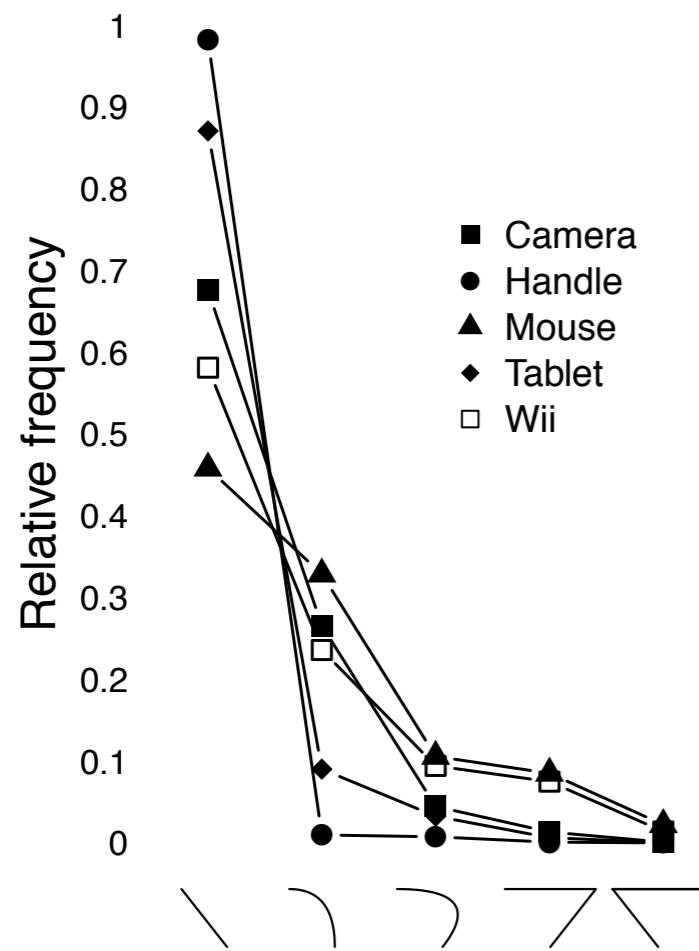


Haslbeck, J. M. B., & Wulff, D. U. (2017). Estimating the Number of Clusters via Normalized Cluster Instability. arXiv:1608.07494

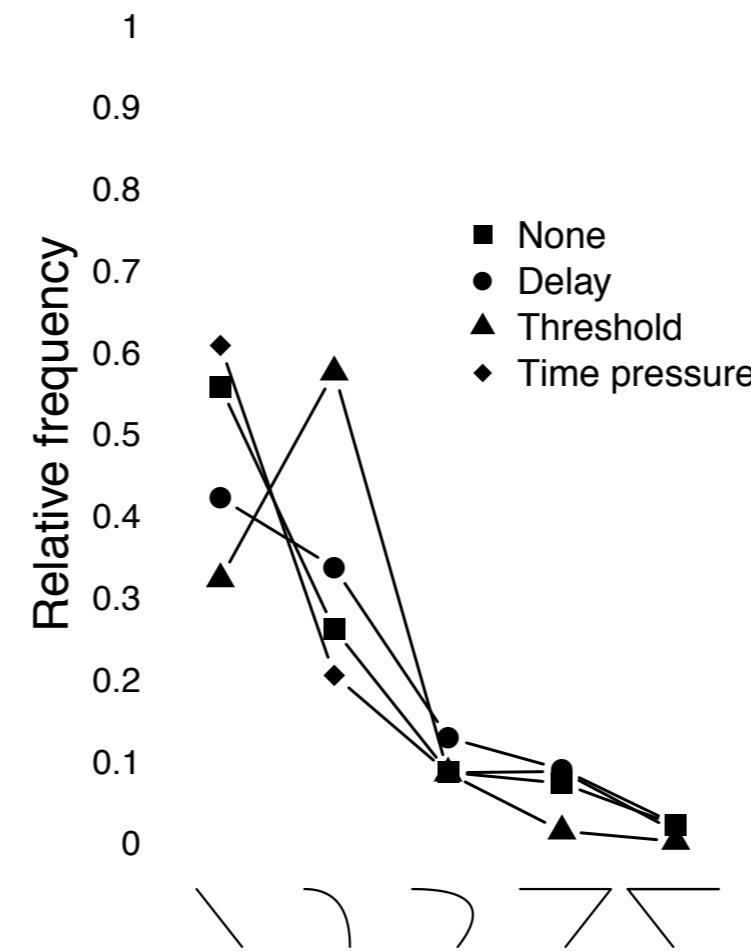
Moderators

of the trajectory distribution

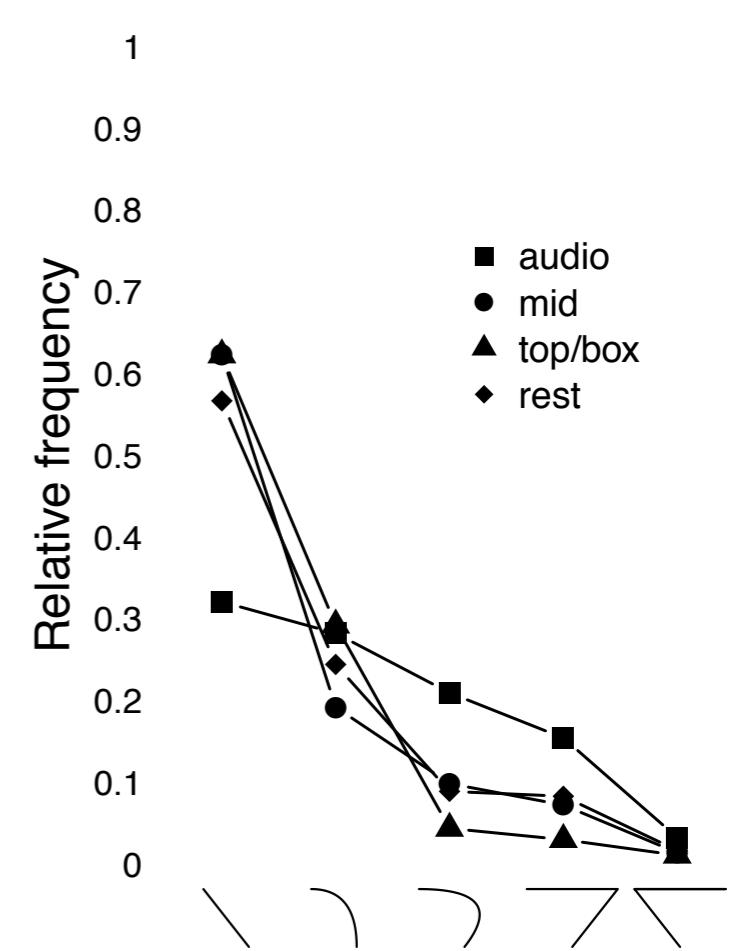
Apparatus



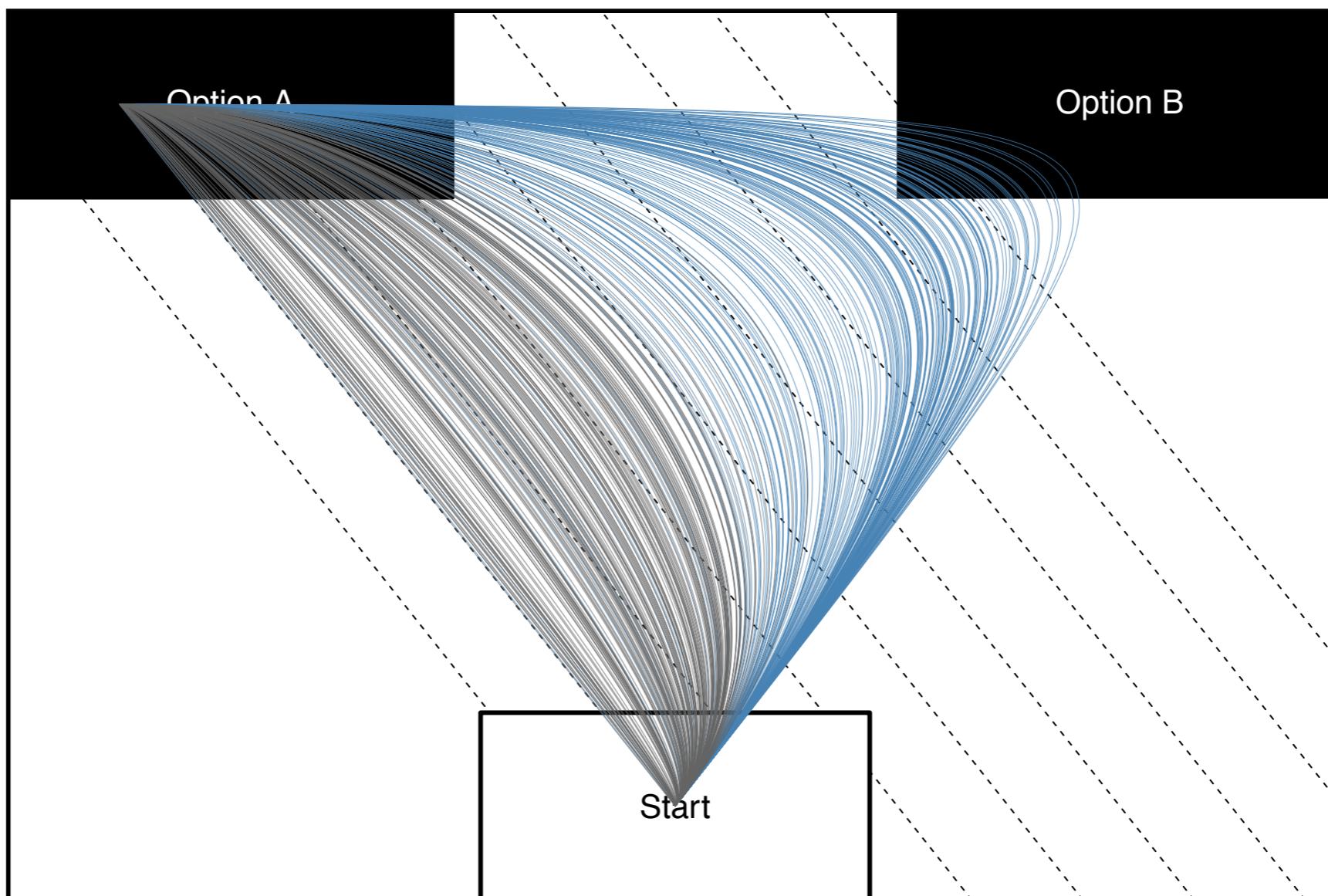
Simultaneity



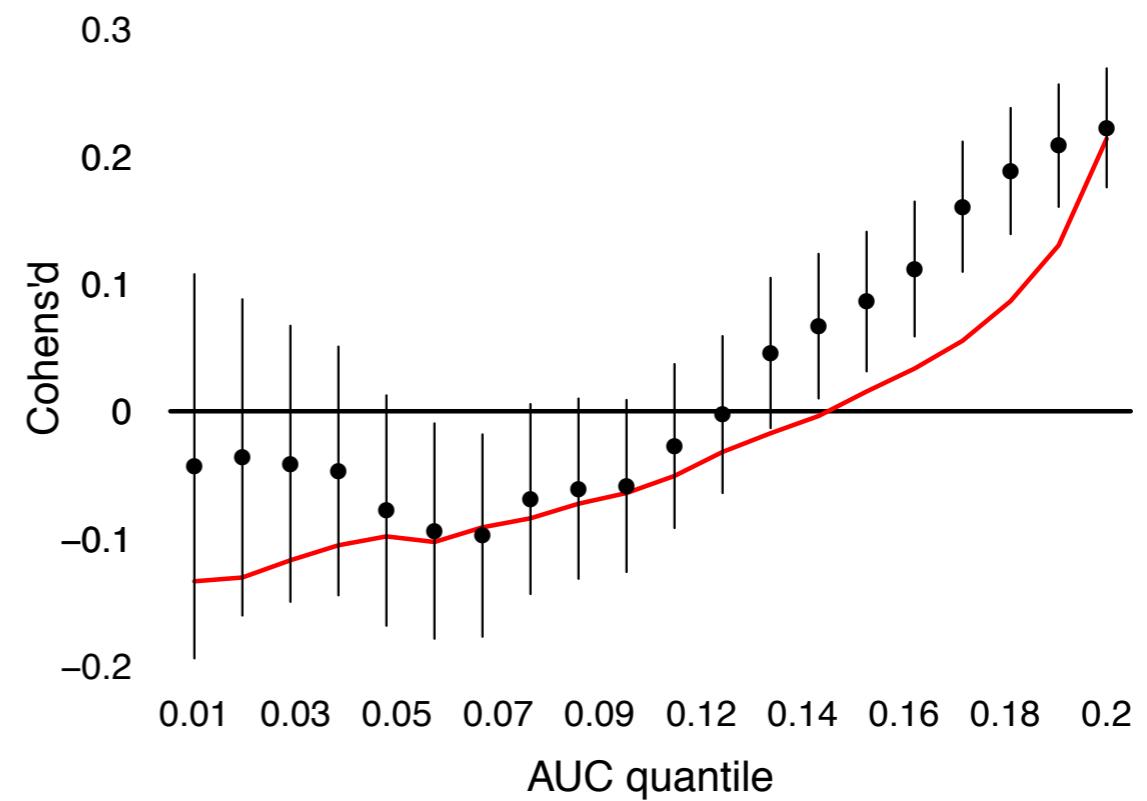
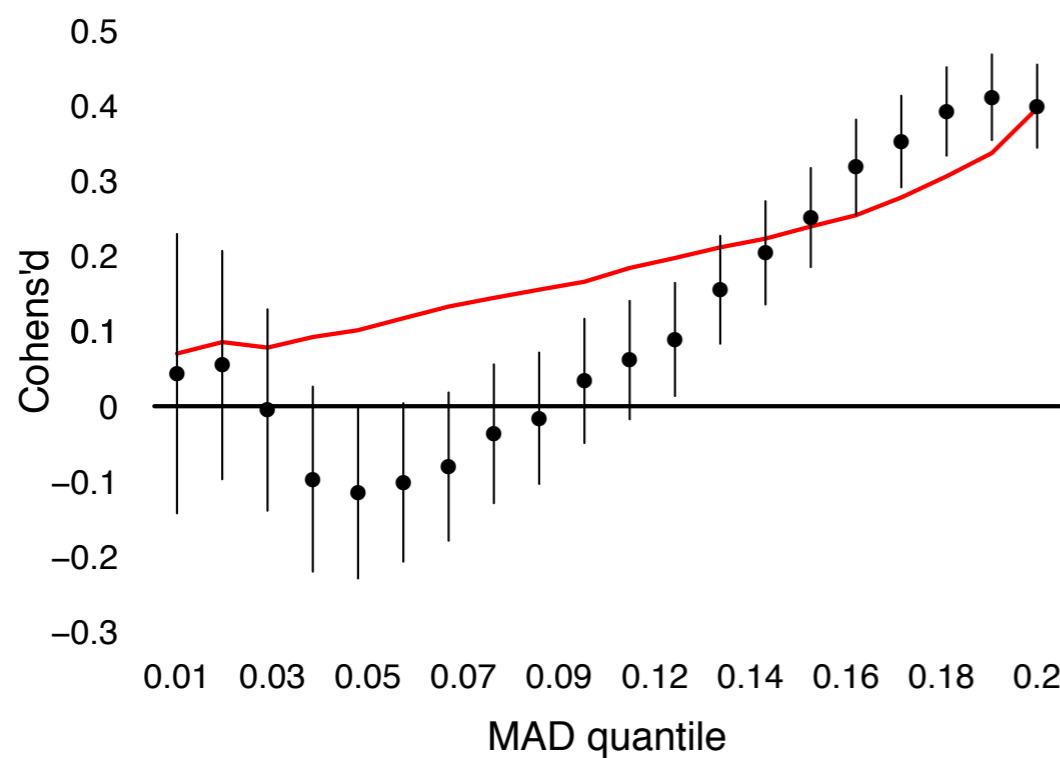
Modality



Quantile-effect plot



Quantile-effect plot



Database

38
articles

2,344 participants

361,607 trajectories



30

2,125

259,153



2

113

4,403



2

50

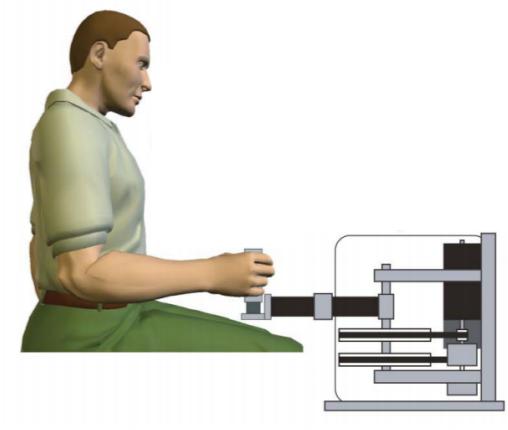
37,786



3

52

26,865



1

4

33,400

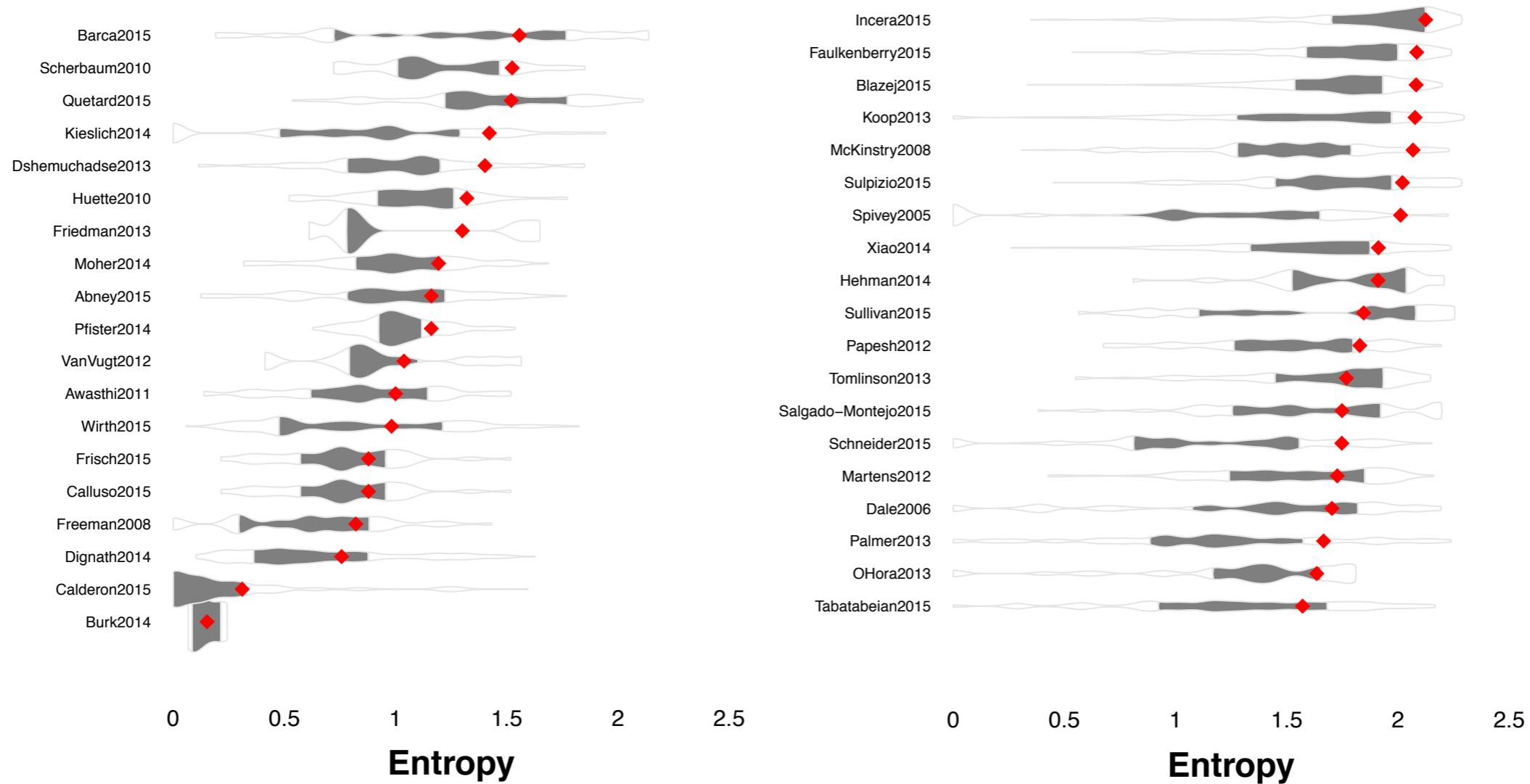
paper

ppt

trials

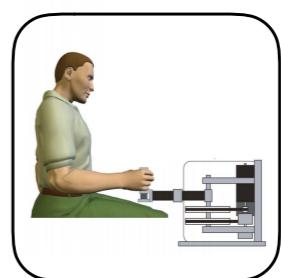
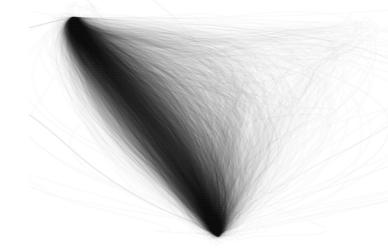
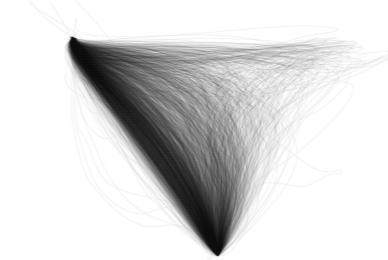
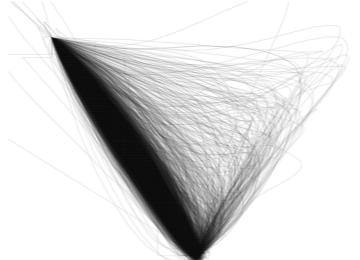
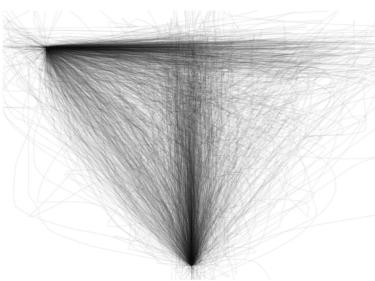
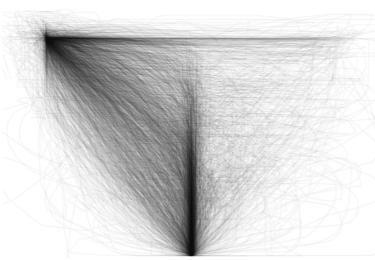
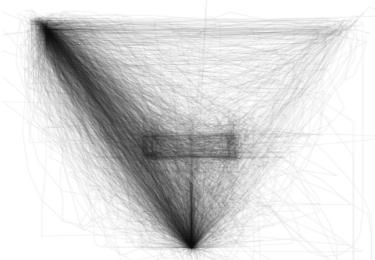
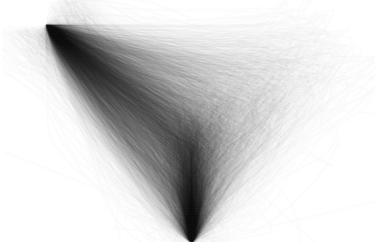
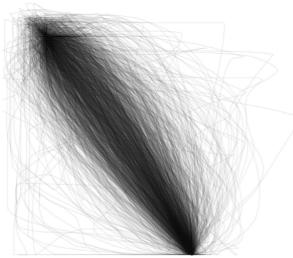
Individual differences

entropy of prototype distribution

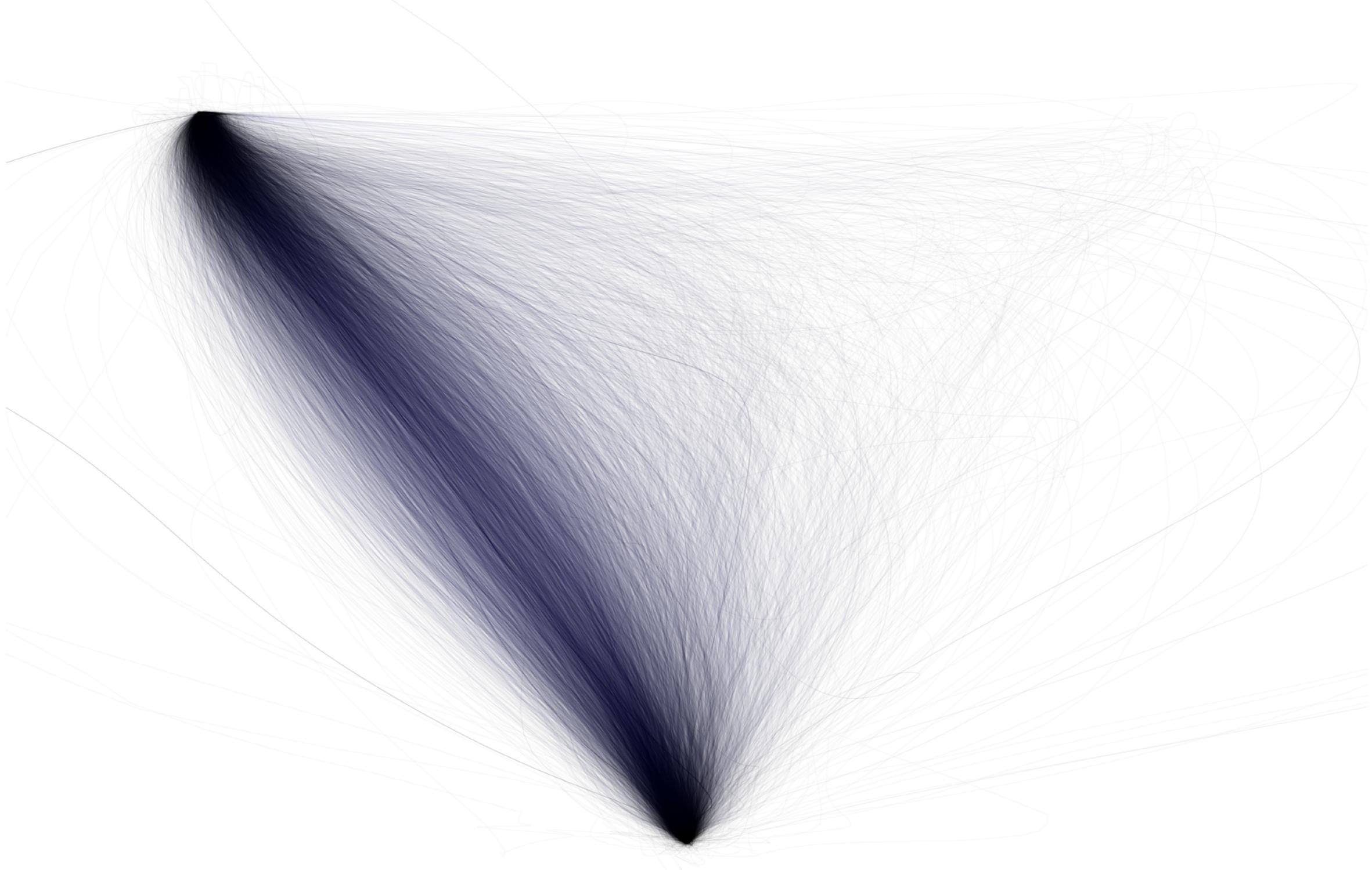


◆ aggregate

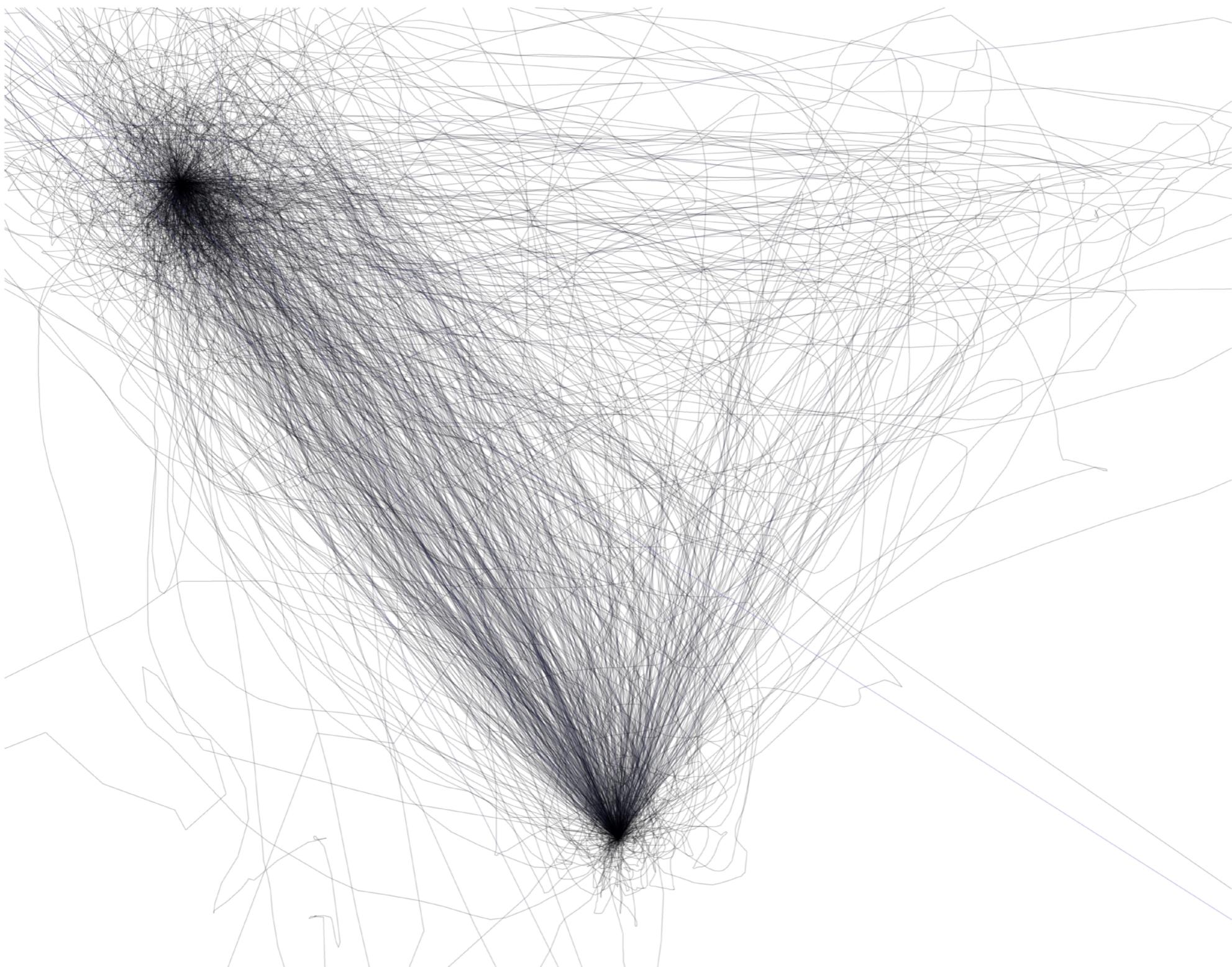
Apparatus



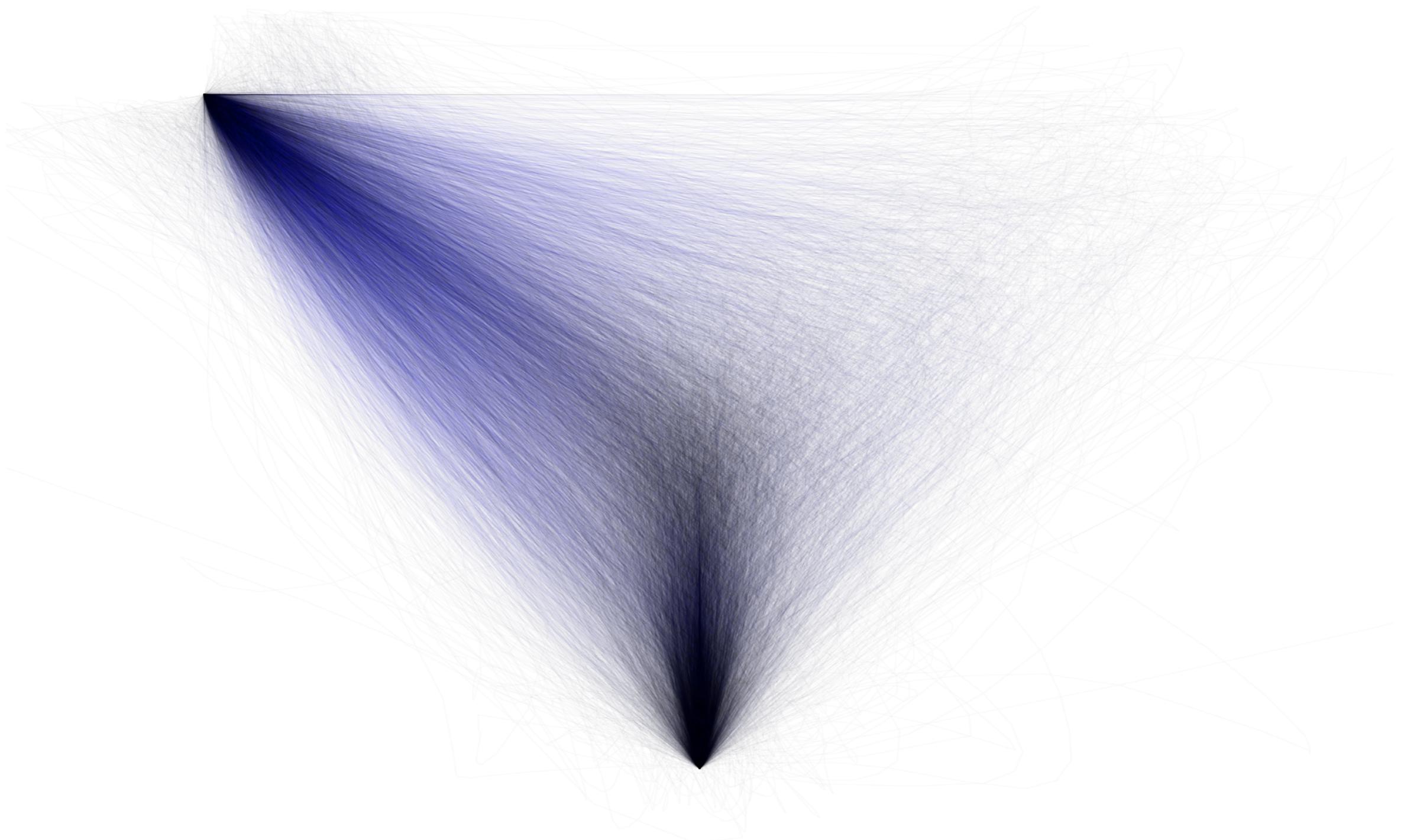
Awasthi et al. 2011



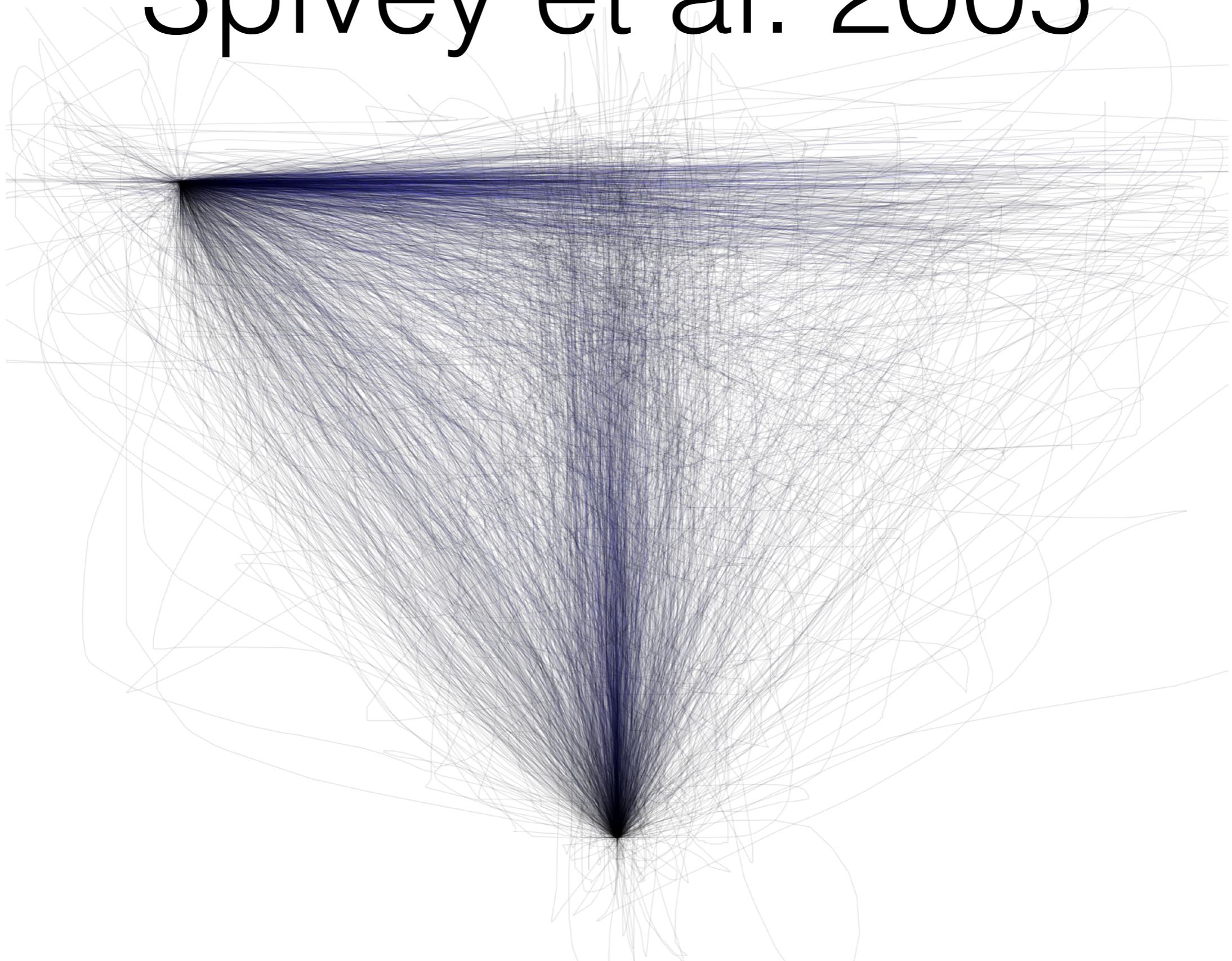
O'Hora et al. 2013



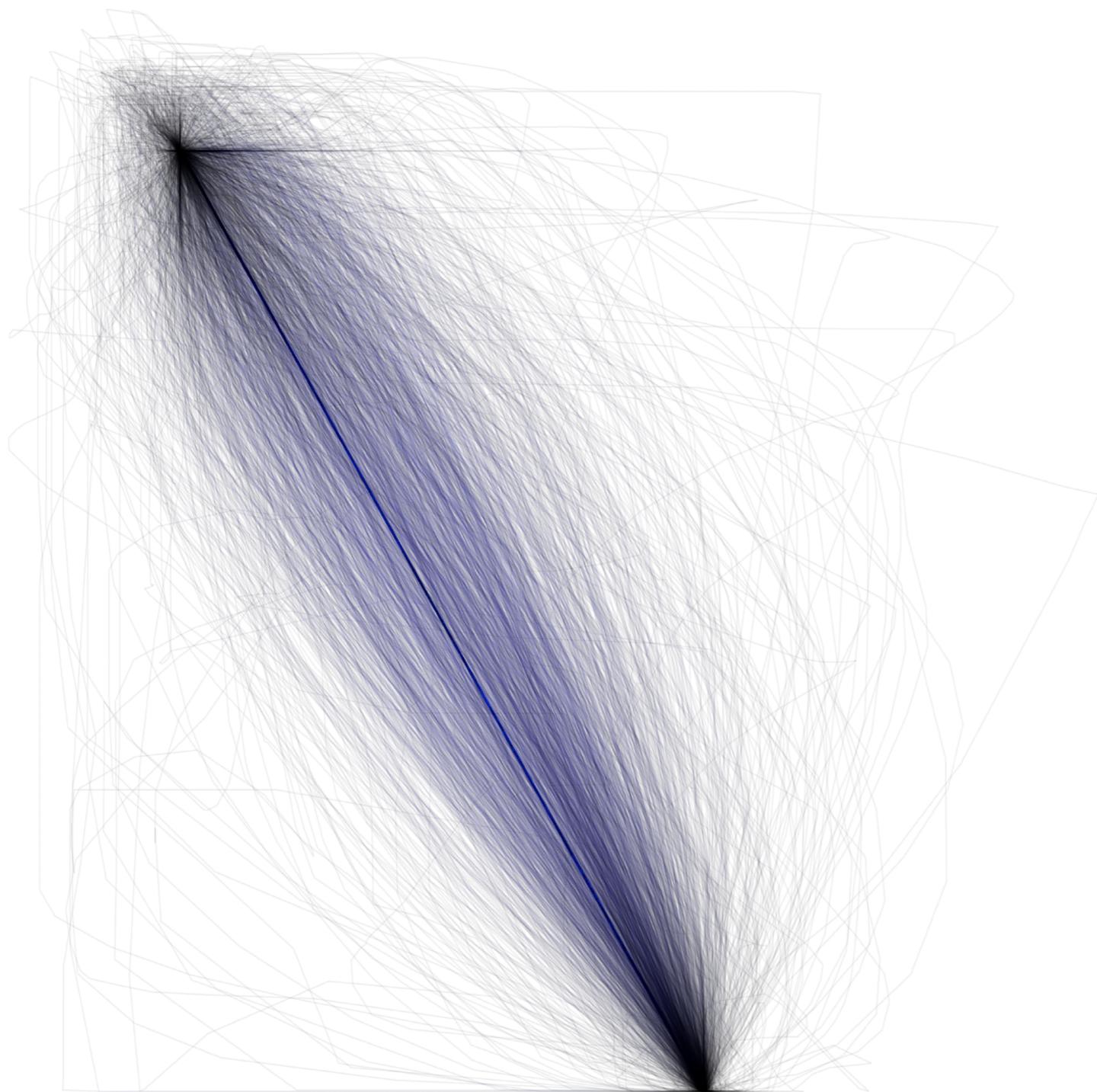
Scherbaum et al. 2010



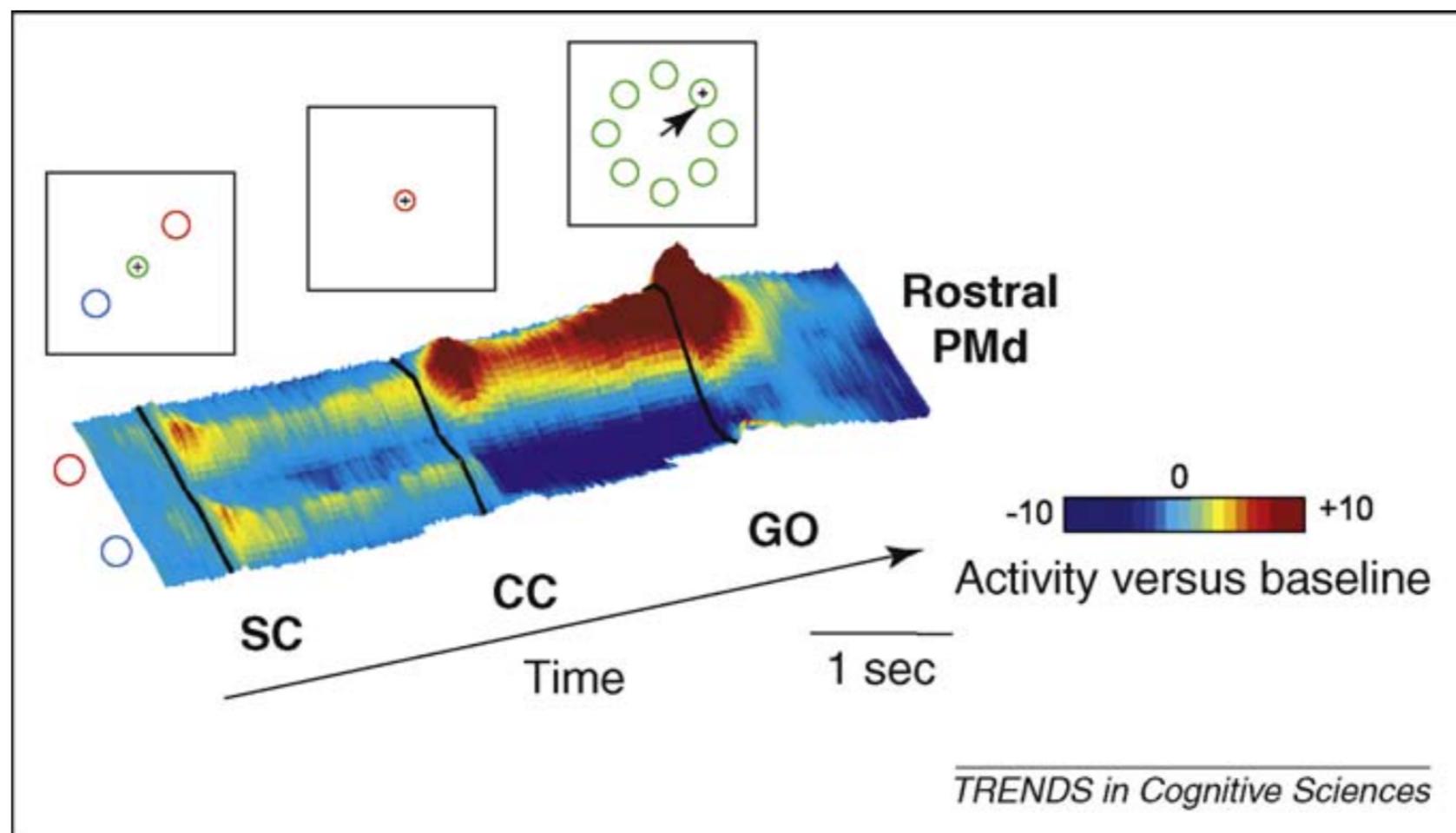
Spivey et al. 2005



Freeman et al. 2008

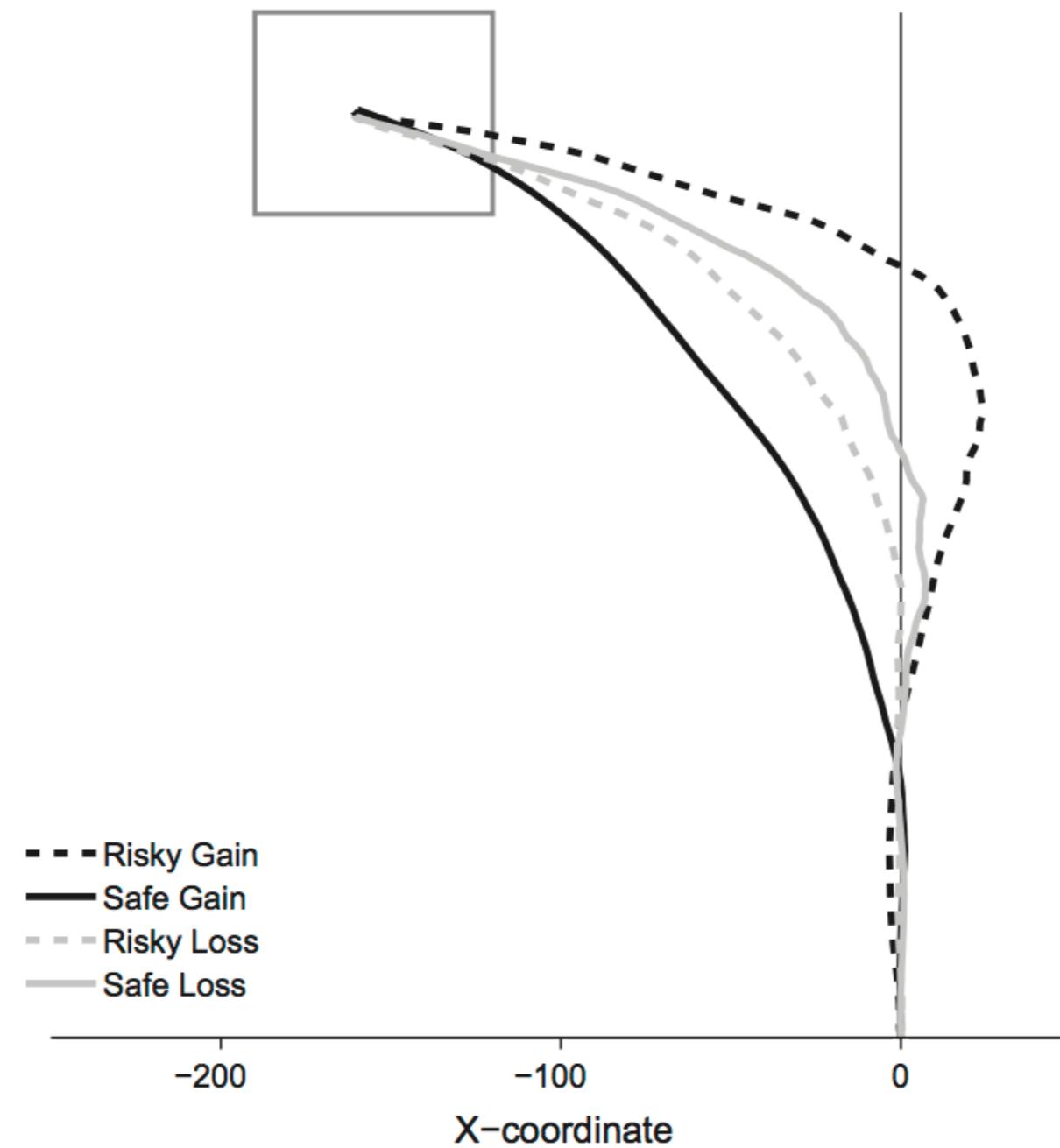


Neurological evidence



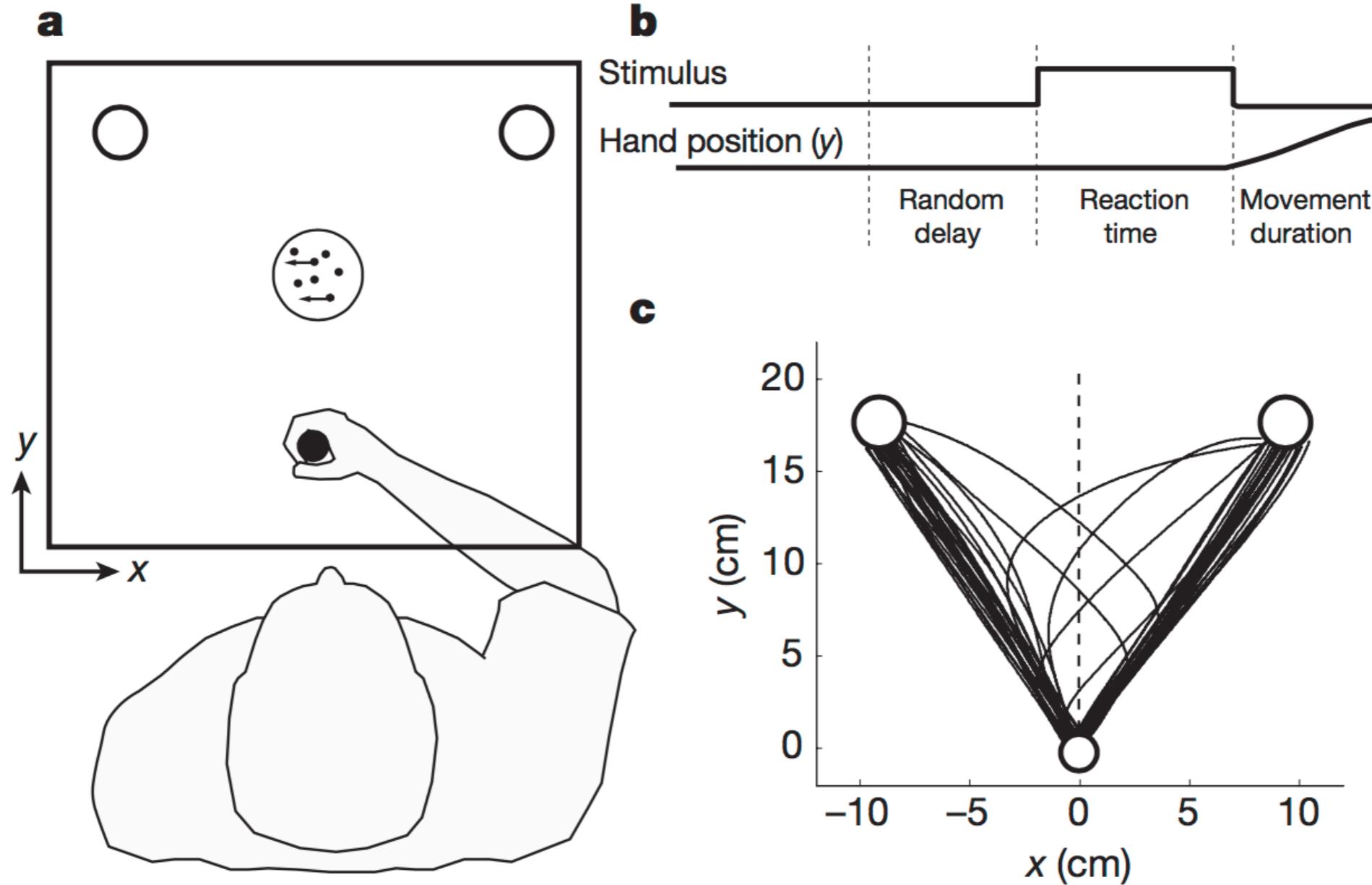
Koop & Johnson, 2013

Cognitive psychology

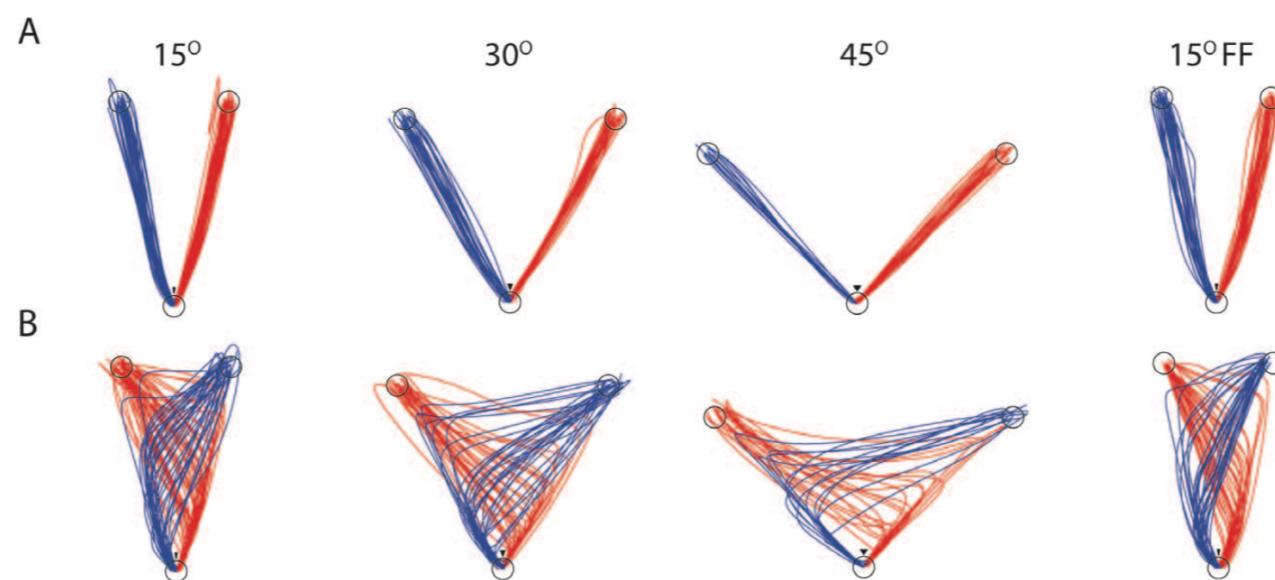
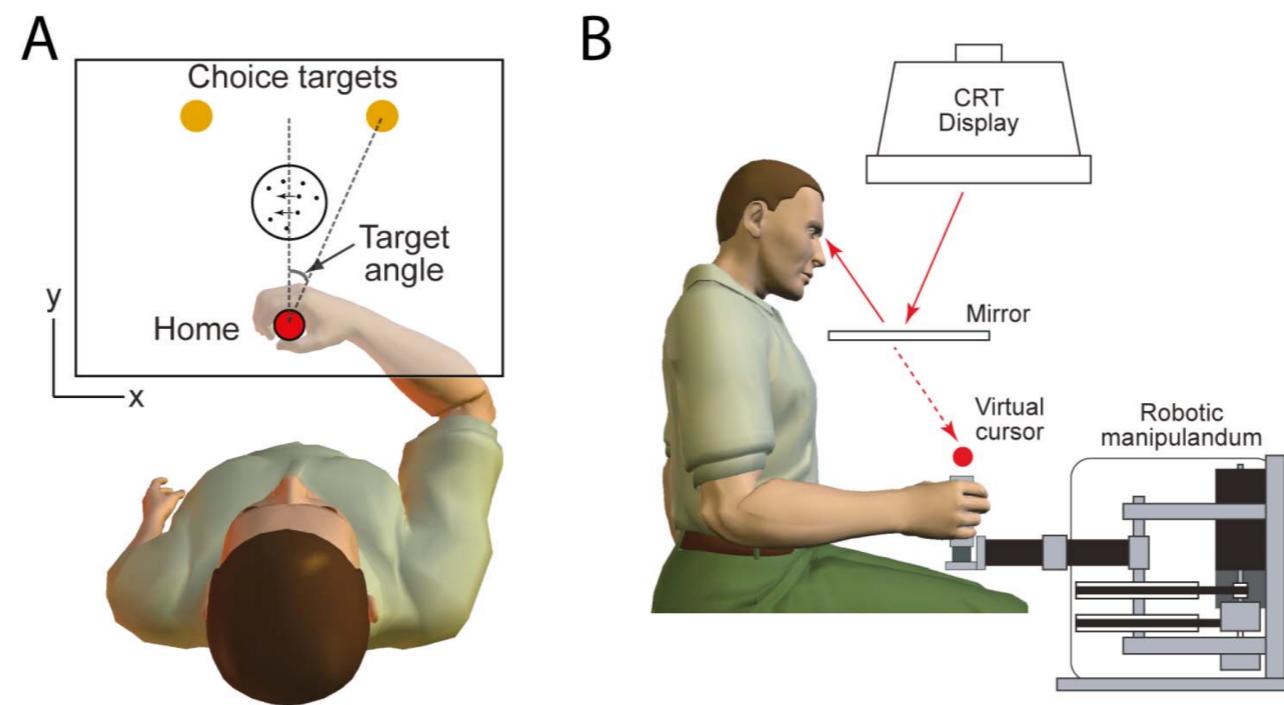


Resulaj et al., 2009

Nature

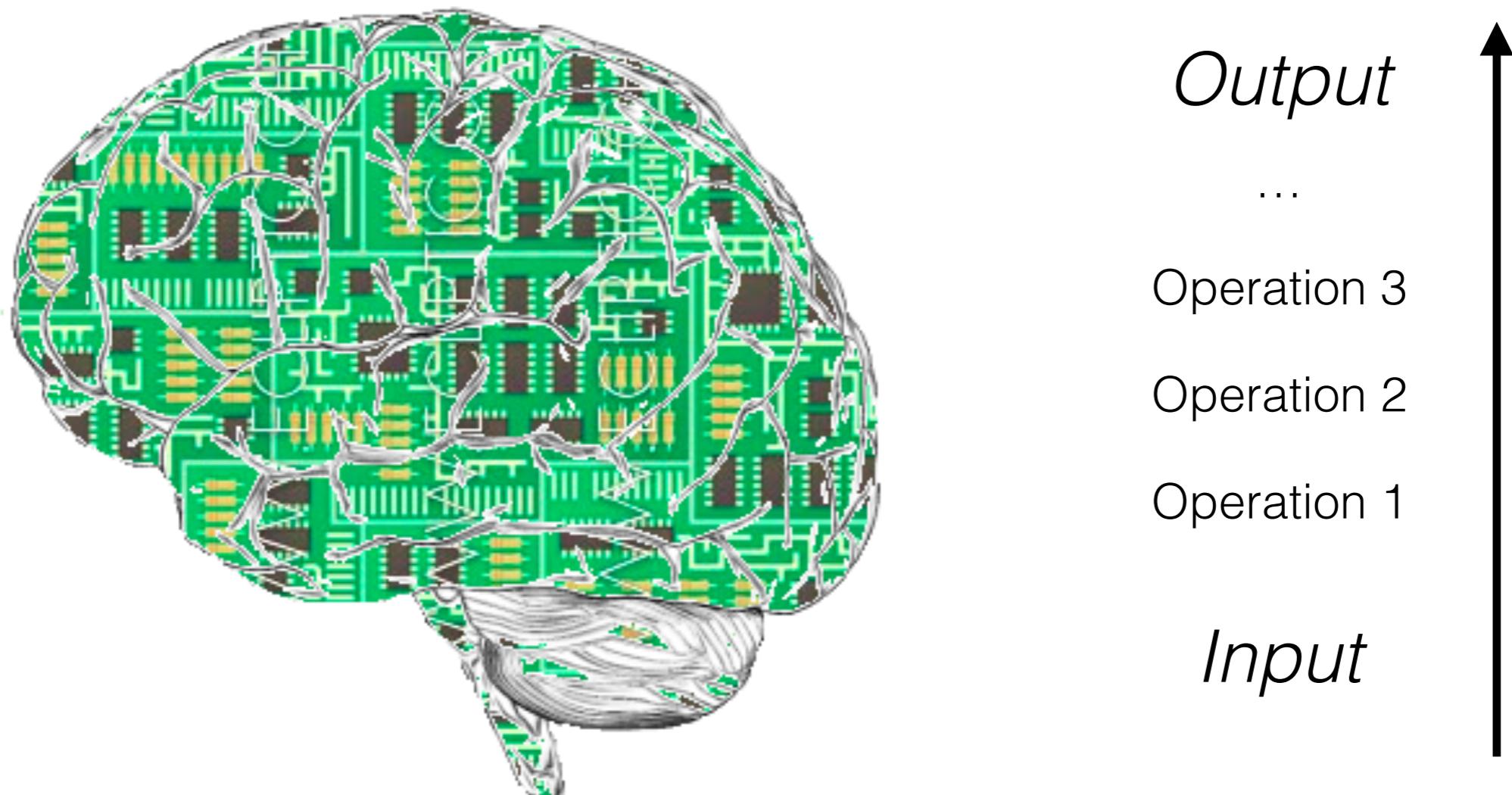


Burk et al. 2014



Mind as a computer

symbolic & serial processing



Mousetracking

Dynamic & concurrent target activation

